Post-Wildfire Debris-Flow & Flooding Assessment: Coconino County, Arizona

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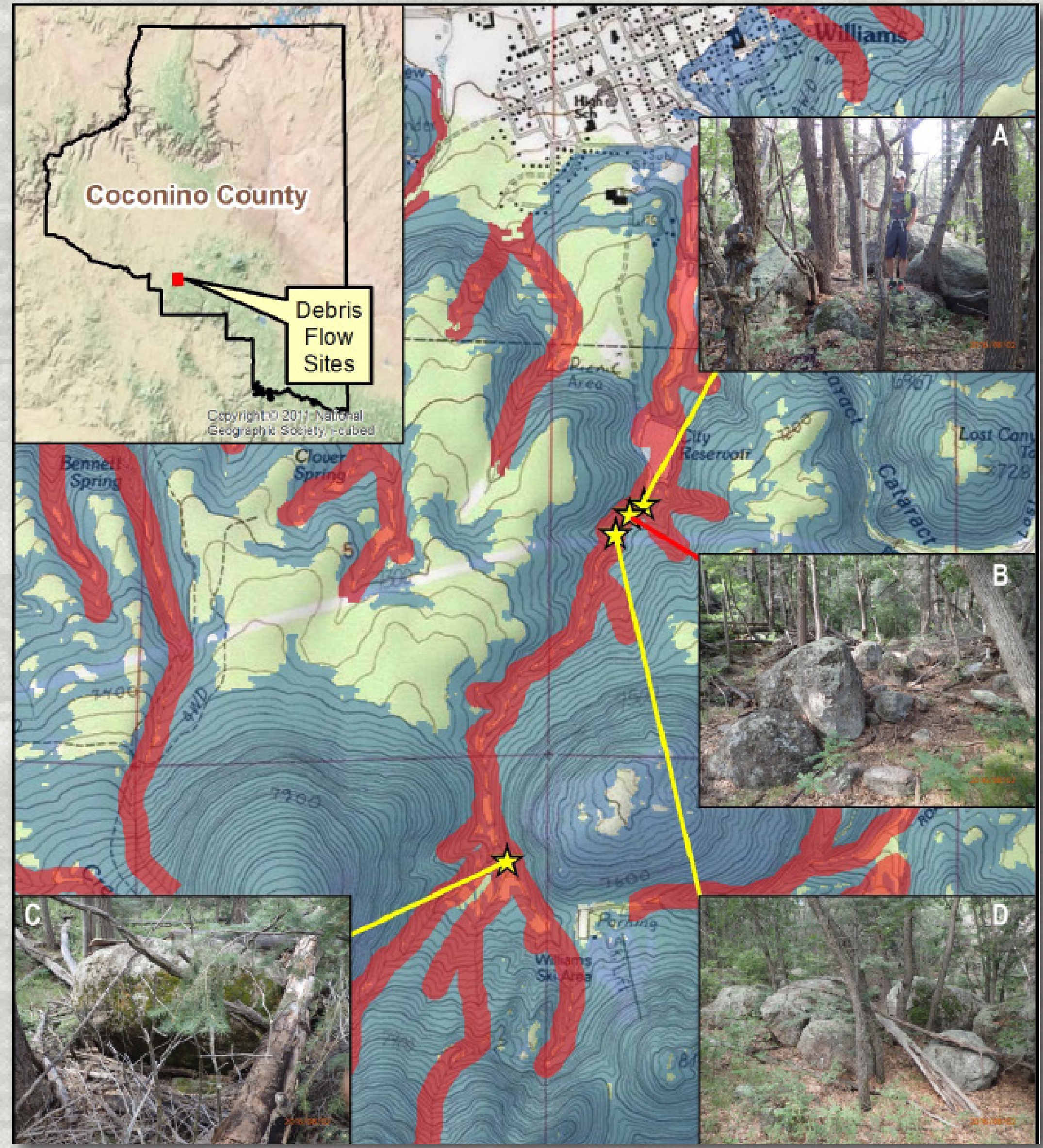
Coconino County
Debris Flow Sites
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Williams
Bennett Spring
Clover Spring
City Reservoir
Cataract
Lost Cany
Parking
Williams Ski Area
A
B
C
D

Pre-Wildfire Field Conditions near Williams, Arizona

August 2017

OPEN-FILE REPORT OFR-17-06

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P.A. Pearthree, Arizona State Geologist and Director

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Post-Wildfire Debris-Flow and Flooding Assessment

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Executive Summary

The Coconino County Post-Wildfire Debris Flow and Flooding Assessment identified areas that are at risk for flooding and debris flows in the aftermath of a reasonable-scenario wildfire. The study consisted of a countywide reconnaissance-level evaluation, and more detailed planning-level evaluation of post-fire flood and debris flow hazards for two pilot study areas in Fort Valley and the City of Williams. The pilot study results were based on field investigations, state-of-the-art two-dimensional FLO2D pre- and post-wildfire flood computer modeling, LAHARZ debris flow computer modeling, and GIS terrain and geographic modeling.

This study concluded that up to 34% of the buildings, and up to 26% of the critical facilities in Coconino County are at some level of increased risk of post-fire flooding, if no actions are taken to reduce the risk of severe wildfires. As many as 593 homes (2,191 parcels) in Coconino County, as well as 13 dams and other critical facilities, may be impacted by post-fire debris flows. Within the two pilot study areas, a reasonable-scenario wildfire could increase flood peaks by a factor of 4-5 times the existing 100-year flood levels, with up to a 350% increase in the number of buildings in flood-prone areas. While debris flows typically will impact only areas with land slopes greater than 5%, the resulting increased sediment deposition downstream of the debris flows will adversely impact properties and infrastructure downstream. Private homes, public buildings, roads, major transportation corridors, water supply, and other public utilities would all be adversely impacted by post-fire floods and debris flows. Maps showing post-fire flood and debris flow hazard areas were developed for the two pilot study areas.

The study also concluded that forest health initiatives can effectively mitigate as much as 58% of the post-fire flood and debris flow risk. However, the watershed modeling demonstrated that treatments such as forest thinning must include the entire watershed, including currently designated wilderness areas, to maximize the treatment benefit. Work in wilderness areas will require increased advanced planning, coordination and permitting with federal agencies. Other recommended risk mitigation actions include implementation of development guidelines to prevent new development from repeating past mistakes, creation of emergency action plans to streamline post-fire recovery efforts, and community awareness and public education activities to build support for safe development and mitigation efforts.

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1 INTRODUCTION

1.1 PURPOSE OF STUDY

Trends of increasing wildfire size and severity across the western U.S.[1] and concurrent encroachment and development into the wildland-urban interface[2] place more people and infrastructure at greater risks from wildfires and the aftermaths of fires. Wildfires dramatically alter watershed hydrologic conditions, substantially increasing the potential for post-fire floods and debris flows[3]. To further complicate matters in the Southwestern U.S., the wildfire season often ends at the onset of monsoonal rainfall, which may ultimately extinguish wildfires while producing large floods and debris flows in the immediate aftermath of a fire. These scenarios allow for very little time to assess post-wildfire damages and hydrologic changes, and to implement mitigation measures.

This phenomenon was highlighted in 2010 by the human-caused Schultz Fire on the Coconino National Forest northeast of Flagstaff, Arizona. The aftermath illustrates the challenges many developed areas have dealing with post-wildfire flooding and debris flows. The Schultz Fire was driven by high winds quickly across the steep eastern slopes of the San Francisco Peaks: approximately 60% of the total 15,075 acres (23.5 sq mi) burned on the first day[4]. Over a thousand residents from nearby housing developments were evacuated, although ultimately no structures were directly impacted by the fire itself. Following the fire, heavy rains from the 4th wettest monsoon on record in Flagstaff resulted in numerous debris flows, significant erosion, and substantial flooding of downstream residential areas[5]. Although the initial debris flows were confined to Forest Service lands, multiple sediment and ash-laden floods downstream of debris flow areas caused extensive damage to residential neighborhoods, homes, property and

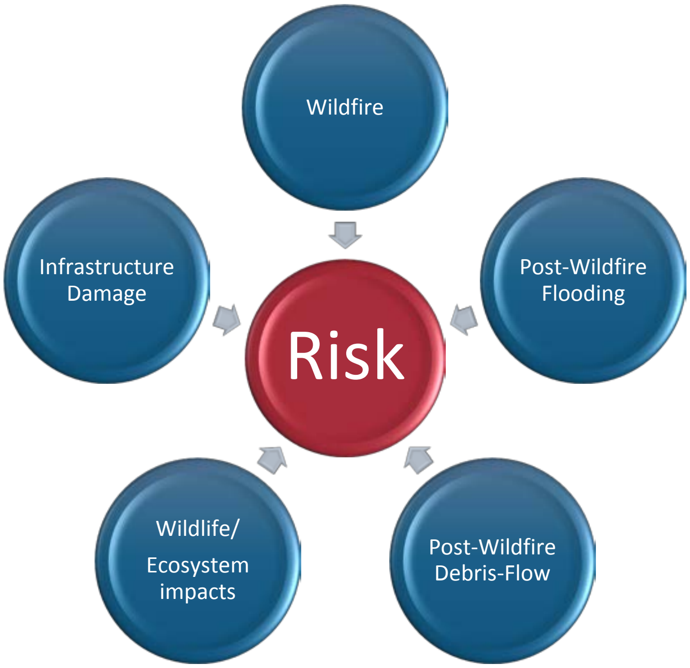

Figure 1 - Risk

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[1] Dennison et al., 2014; Westerling et al., 2006; Williams et al., 2010
[2] Moritz et al., 2014; Stein et al., 2013
[3] Moody and Ebel, 2012; Neary et al., 2005; Riley et al., 2013
[4] USDA Forest Service, 2010
[5] Youberg et al., 2010

infrastructure up to four miles from the burn area[5]. The risk that wildfires pose (Figure 1) on local communities can take many forms, many which happen after the fire has been extinguished.

The purpose of this study was twofold; first to determine areas within Coconino County which may be at risk for flooding and debris flows in the aftermath of a reasonable-scenario wildfire, and second to determine the extent and severity of that risk in two pilot study areas (Williams and Fort Valley).

This study has been done cooperatively between FEMA, Coconino County, Arizona Geological Survey (AZGS) and JE Fuller to identify previously unrecognized debris flow and flood risk zones. Results from this study provides information to help Coconino County, local communities and the U.S. Forest Service identify areas that should be targeted for fuel reduction treatments, develop appropriate emergency response plans and devise strategies to increase a community's resilience to post-fire floods and debris flows.

1.2 SCOPE OF STUDY

This project includes a multi-stepped approach (Figure 2) to understanding where there are post-fire flood and debris flow risks within Coconino County and the potential severity. Each phase of the project was done in cooperation with Coconino County, JE Fuller, and the AZGS.

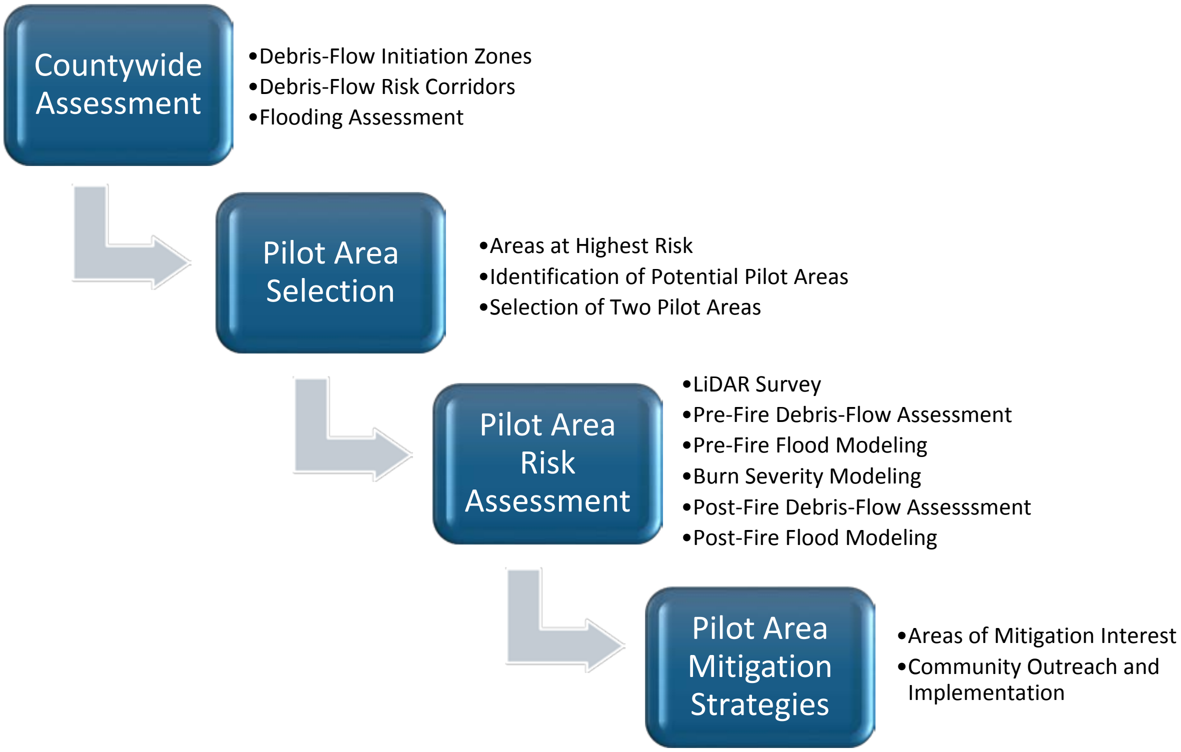
Countywide Assessment
•Debris-Flow Initiation Zones
•Debris-Flow Risk Corridors
•Flooding Assessment
Pilot Area Selection
•Areas at Highest Risk
•Identification of Potential Pilot Areas
•Selection of Two Pilot Areas
Pilot Area Risk Assessment
•LiDAR Survey
•Pre-Fire Debris-Flow Assessment
•Pre-Fire Flood Modeling
•Burn Severity Modeling
•Post-Fire Debris-Flow Assesssment
•Post-Fire Flood Modeling
Pilot Area Mitigation Strategies
•Areas of Mitigation Interest
•Community Outreach and Implementation

Figure 2 - Process

A summary of each phase of this project is presented in the following sections.

1.3 STUDY METHODOLOGY

Two pilot study areas were selected for more detailed analyses. Two burn scenarios for the City of Williams area were developed by the US Forest Service (USFS). For the Fort Valley area, forest burn severity was modeled by JE Fuller for three different cases in utilizing FlamMap Version 5[6]. The results of the fire severity models were used to model changes in flood and debris flows risk. FlamMap utilizes a series of user-specified input parameters to approximate fire behavior over a landscape. The input parameters can be calibrated using data from recent nearby fires, and varied to produce reasonable fire behavior results. Many of the parameters utilized for the Fort Valley area were provided to JE Fuller by the Coconino National Forest. These parameter files were used to represent conditions in which the fire is burning and, in the case of Fort Valley, parameters were used to closely represent conditions found at the time of the 2010 Schultz Fire. We chose to use parameters similar to the Schultz Fire to compare modeling results with previous post-fire responses. All model runs were completed using the Scott/Reinhardt crown fire calculation method.[7] The selected output included Crown Fire Activity and Heat/Unit Area.

FLO-2D PRO was chosen as the combined hydrologic and hydraulic model for both the pre- and post-fire conditions analysis. FLO-2D is a two-dimensional, flood routing model that simulates unconfined overland flow over complex topography. This modeling platform was chosen because of the distributary and unconfined sheet flooding conditions in the Fort Valley area. The model includes components such as rainfall, infiltration, and hydraulic structures (e.g., bridges, levees, culverts, etc.). An emphasis of this study is to understand and quantify the impact of increased forest health due to forest treatments (thinning, control burns, etc.) on downstream flood risk.

Debris flow inundation zones were determined in several steps. First, geomorphic data collected after the Schultz Fire was used to evaluate the current U.S. Geological Survey (USGS) post-fire debris flow volume model[8] with mapped post-Schultz Fire deposits[9]. The purpose of this step was to assess how well modeled debris flow volumes compare to volume estimates derived from field mapping. These data were then used to select volumes for modeling potential inundation zones with LAHARZ[10]. LAHARZ is an empirical model first developed to identify potential hazard zones from lahars, a type of volcanic flow. LAHARZ was later modified to include rock avalanches and debris flows, and subsequently adapted to model Arizona debris flows. LAHARZ is an ArcMap toolbox add-in. It provides a first-order approximation of the area that could be inundated by a debris flow for a given flow volume. Modeled LAHARZ inundation zones were compared with mapped post-Schultz Fire deposits to inform the interpretation of model results in the pilot study areas. The pilot study areas were assessed using the current USGS post-fire debris flow probability and volume models[6], and potential inundation zones were identified using LAHARZ[8].

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[6] Joint Fire Sciences Program, 2015

[7] Stratton, 2009

[8] Gartner *et al.*, 2014; Staley *et al.*, 2017

[9] Youberg, 2015

[10] Schilling, 1998; Schilling, 2014

2 COUNTY-WIDE ASSESSMENT

2.1 IDENTIFICATION OF POST-WILDFIRE DEBRIS-FLOW RISK CORRIDORS

The first project task consisted of a County-wide reconnaissance-level assessment of wildfire and debris flow vulnerable lands. The assessment was completed using Geographic Information System (GIS)-based analyses utilizing the following data and sources:

- Topography – (USGS 10-meter digital elevation model)
- HUC-12 Watersheds – (Hydrologic basins delineated by USGS)
- Land Ownership and Assessor Parcels – (Coconino County GIS)
- Buildings – (Coconino County GIS)
- Jurisdictional Dams – (Arizona Department of Water Resources)
- Highways, Railways, and Streets – (Coconino County GIS)
- Severe Fire Potential – (U.S. Department of Agriculture)
- Critical Facilities – (Coconino County Multi-Jurisdictional Hazard Mitigation Plan)
- Gas Transmission Mains – (Energy Transfer and Kinder Morgan)

Debris Flow Risk Corridors were determined by assigning a 100-meter wide corridor to stream flow networks developed from USGS 10-meter digital elevation models (DEM). Research indicates that debris flow initiate on slopes ranging from 15 degrees (27%) to greater than 40 degrees (84%)[11]. Analysis of debris flows after the 2010 Schultz Fire suggests the runout of most debris flows did not extend beyond a 5-degree slope. Thus, the County-wide debris flow risk corridors developed for this study (Figure 3) begin at slopes above 15 degrees and end where the slope reduces to less than 5 degrees (9%). All the corridors originate in watersheds that have potential for moderate to high severity wildfires.

The debris flow risk dataset provides Coconino County with a valuable county-wide planning tool to identify areas subject to debris flow hazards after wildfires. Although this analysis produced in county-wide results, it is recognized that debris flows in some areas would have more severe consequences than in others. For example, post-wildfire debris flow risk corridors that intersect dams, buildings, roads, and other infrastructure would be far more devastating than a debris flow risk corridor that occurred on undeveloped public land (Table 1).

Table 1 - Debris Flow Risk Corridor Weighting Criteria

Criteria	Number of Features within the Debris Flow Risk Corridors
Dams	13
Critical Facilities	10
Buildings	593
Highways, Railways, Streets, Pipelines	1,279
Parcels	2,191

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[11] Melton, 1965, Takahashi, 1981; Rickenmann and Zimmermann, 1993; Coe and others, 2008; Webb and others, 2008a; Kean and others, 2013; Youberg, 2014

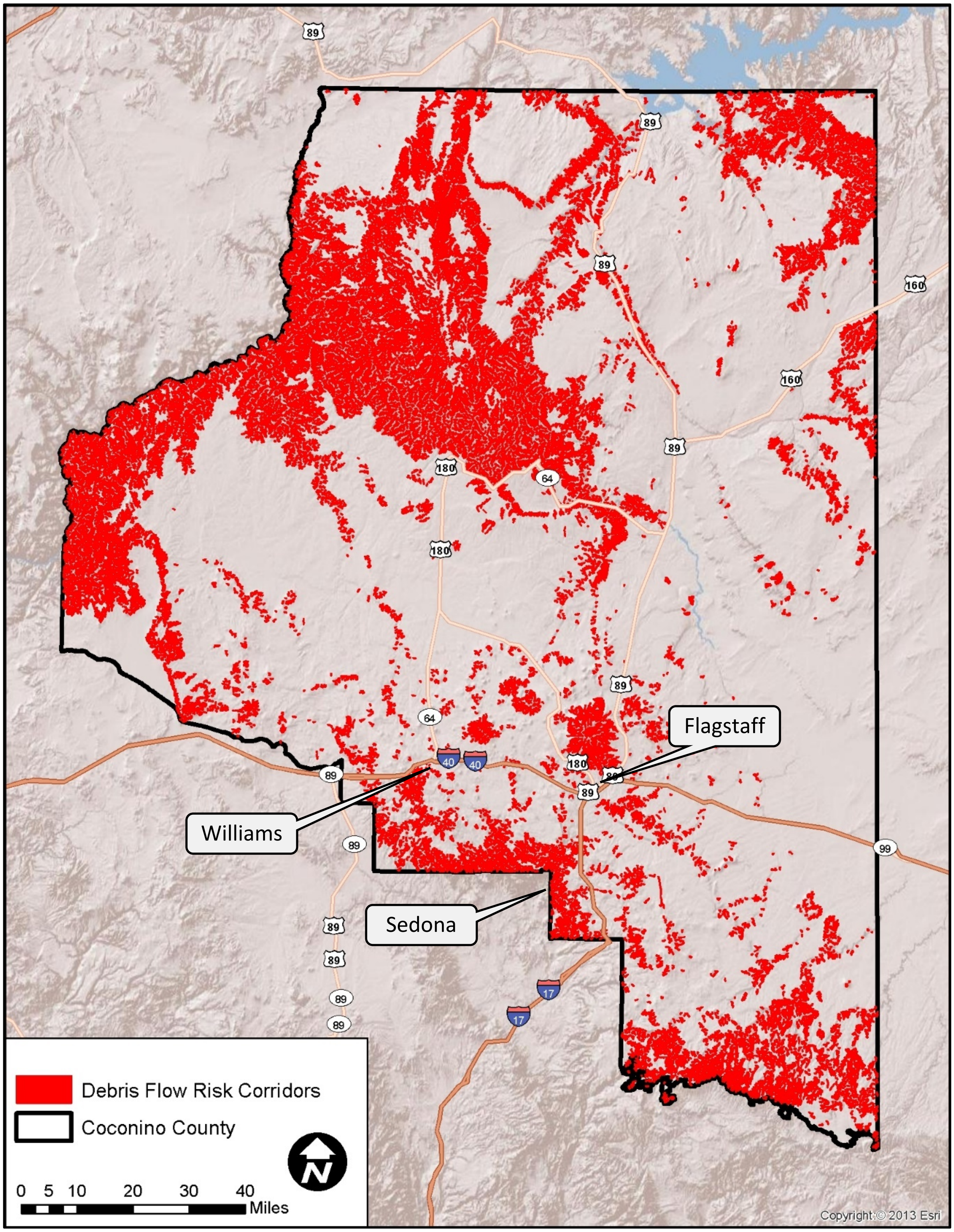
89
89
89
160
160
89
180
64
180
89
Flagstaff
64
40
40
180
89
89
89
Williams
89
99
Sedona
89
89
89
89
17
17
Debris Flow Risk Corridors
Coconino County
N
0 5 10 20 30 40
Miles
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Figure 3 - Post-Wildfire Debris Flow Risk Corridors

The results shown in Table 1 and Figure 3 clearly indicate that post-fire debris flows are a significant risk to public infrastructure and private land in Coconino County.

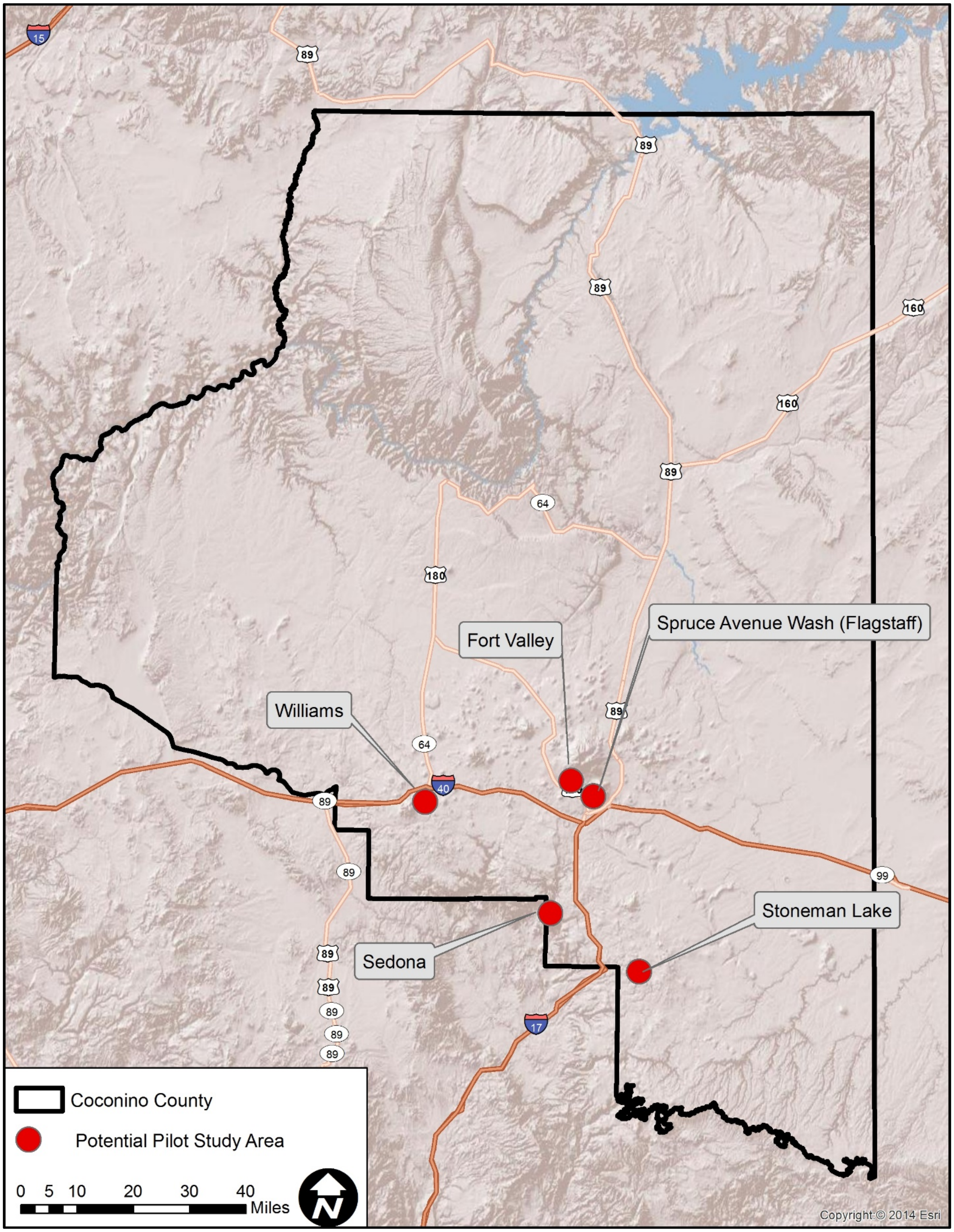
2.2 POTENTIAL PILOT AREA IDENTIFICATION AND SELECTION

The debris flow risk corridors were used as a guide to highlight potential pilot study areas. These risk areas are generally confined to specific flow path(s) within a larger watershed. With this understanding, potential pilot study areas were defined by delineating a watershed which encompasses the debris flow stream corridor, as well as the potential flood risk area.

The process of identifying areas prone to post-wildfire debris flow and flood risks relied on a numerical ranking scheme based on the number of structures, parcels, etc. impacted, as well as application of common sense and engineering judgment to find watersheds that appear to be at risk. Five areas within the County were identified for consideration (Table 2, Figure 4). After inspection of the maps and the numerical ranking results, two areas, Williams and Fort Valley, were selected as the best candidates for detailed pilot studies.

Table 2 - Potential Pilot Areas

#	Name	HUC-12 Watershed Name	Area of Debris Flow Study	Flooding study	Community Impacted
1	Williams	Cataract Creek Headwaters	Upper Cataract Creek drainages/ High School Hill	Cataract Creek drainages extending to I-40	City of Williams
2	Fort Valley	Upper Rio De Flag	Big and Little Leroux Spring area	Upper Rio de Flag watershed ending at South Snow Bowl Road	Fort Valley
3	Spruce Avenue Wash	Lower Rio De Flag	East side of Dry Lake Hills/west side of Mount Elden	Spruce Avenue Wash watershed	City of Flagstaff
4	Sedona	Middle Oak Creek	Multiple drainages within the Sedona Area	Multiple drainages that outlet into Oak Creek. Oak Creek is not included.	City of Sedona
5	Stoneman Lake	Red Tank Draw	East Side of Stoneman Lake	East Side of Stoneman Lake	Ponderosa Paradise



15
89
89
89
160
160
89
64
180
Fort Valley
Spruce Avenue Wash (Flagstaff)
Williams
89
64
40
89
89
99
Stoneman Lake
Sedona
89
89
89
89
89
17
Coconino County
Potential Pilot Study Area
0 5 10 20 30 40
Miles
N
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Figure 4 - Potential Pilot Study Areas

The Williams Pilot Area was selected for the following reasons:

- The watershed has a high potential to burn.
- Potential for debris flows to directly impact homes is high.
- Two drainages have reservoirs used as a source of city water. Debris flows and post-fire flooding may negatively impact the municipal water.
- A large number of structures may be inundated after a fire.
- The Kaibab National Forest had already developed burn scenarios that could be used to generate proxy burn severity maps for the Bill Williams Mountain area.
- The area on the north side of Bill Williams Mountain had been scheduled for forest treatments, but the treatments have been delayed indefinitely.
- The study and community outreach has the potential for a cooperative effort with the City of Williams.

The Fort Valley Pilot Area was selected for the following reasons:

- FLO-2D mapping has been done for the area. Since the base mapping was complete, pre- and post-thinning burned conditions could be readily modeled.
- Since an Initial Engineering Assessment (IEA) was recently completed by the County for this area, the pilot study area would be the next logical step in modeling flooding impacts and the benefit of mitigation.
- Fort Valley is in the unincorporated portion of the County, so any recommended planning or mitigation measures do not need to be coordinated with any other towns or cities.
- Fort Valley's location in the San Francisco Peaks is similar to the Timberline area relative to Schultz Peak. Timberline was severely impacted from post-wildfire floods and debris flows following the 2010 Schultz Fire. Fort Valley would likely see similar impacts if a similar wildfire and rainfall occurred on the forested slopes above this community.

3 FORT VALLEY RISK ASSESSMENT

The Fort Valley Pilot Area was studied to understand the pre- and post-wildfire risks associated with flooding and debris flows. To accomplish a full comparison of pre-and post-fire risks, the following watershed conditions were studied and are described in the following sections.

- Pre-Fire (unburned)
- Post-Fire, No Treatment
- Post-Fire, Treatment up to 8,200 Feet (Excluding the Kachina Peaks Wilderness Area)
- Post-Fire, Treatment (all areas)

3.1 PRE-WILDFIRE RISK ASSESSMENT

3.1.1 Assessment of Past Debris Flow Occurrence

The goal of this phase of the study was to assess if the Fort Valley watersheds could have debris flows after a wildfire. To do this, reconnaissance field investigations were conducted to determine if evidence of past debris flows is present in the main drainages leading to Fort Valley. Field observations were made at various locations on three main drainages at the north end of Fort Valley.

On all the main drainage channels, boulder deposits were found that had levee- and snout-like forms, which are probably associated with past debris flows (Figure 5). Most of these deposits were located in the lower elevation channel areas and on alluvial fans, while many were found within and adjacent to the channels higher in the basins. Debris flow-like boulder deposits were also found on several, but not all, tributary drainages, typically at the confluence with the main drainage.

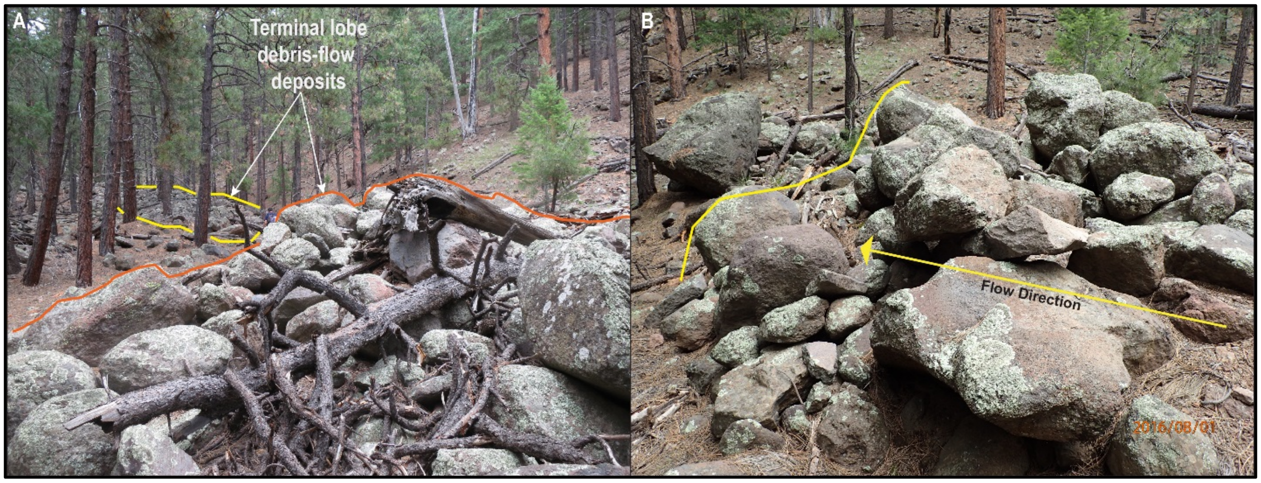
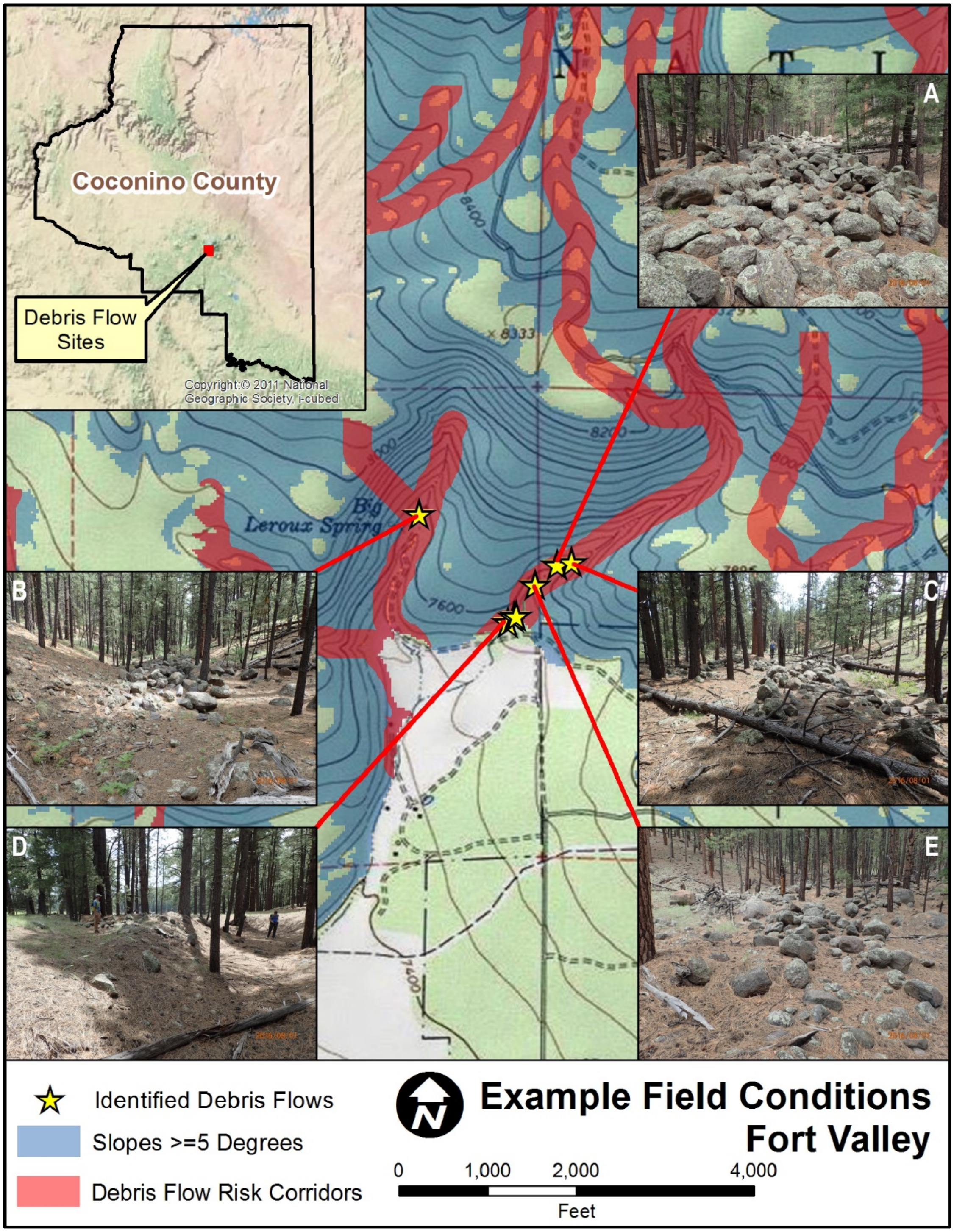


Figure 5 - Bulbous boulder deposits

Debris flow deposits were documented in the Fort Valley pilot study area in most channels that were assessed (Figure 6), and the observed deposits appear to agree well with the assumptions made in countywide assessment. These deposits are not dated but are likely geologically recent. Evidence of debris flows were limited to the base of channel areas and fan apexes. Deposits far from the channels were not observed, but may be present. Although debris flows may not travel far beyond an alluvial fan apex, sediment-laden floods will and will be exacerbated by the occurrence of debris flows. Therefore, it was concluded that the Fort Valley area is subject to risk of post-fire debris flows.


Coconino County
Debris Flow Sites
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A
B
C
D
E
Big Leroux Spring
8400
8333
8200
8000
7600
7400
Identified Debris Flows
Slopes >=5 Degrees
Debris Flow Risk Corridors
N
Example Field Conditions
Fort Valley
0
1,000
2,000
4,000
Feet

Figure 6 - Fort Valley Pre-Wildfire Field Conditions

3.1.2 Pre-Wildfire Flooding Assessment

The pre-wildfire flood risk was estimated for the 2-, 10-, and 100-year events for the Fort Valley Area. The full results are not presented in this report, but a detailed description of the pre-fire flooding assessment is provided in Appendix B. Figure 7 shows the pre-wildfire 100-year depth results.

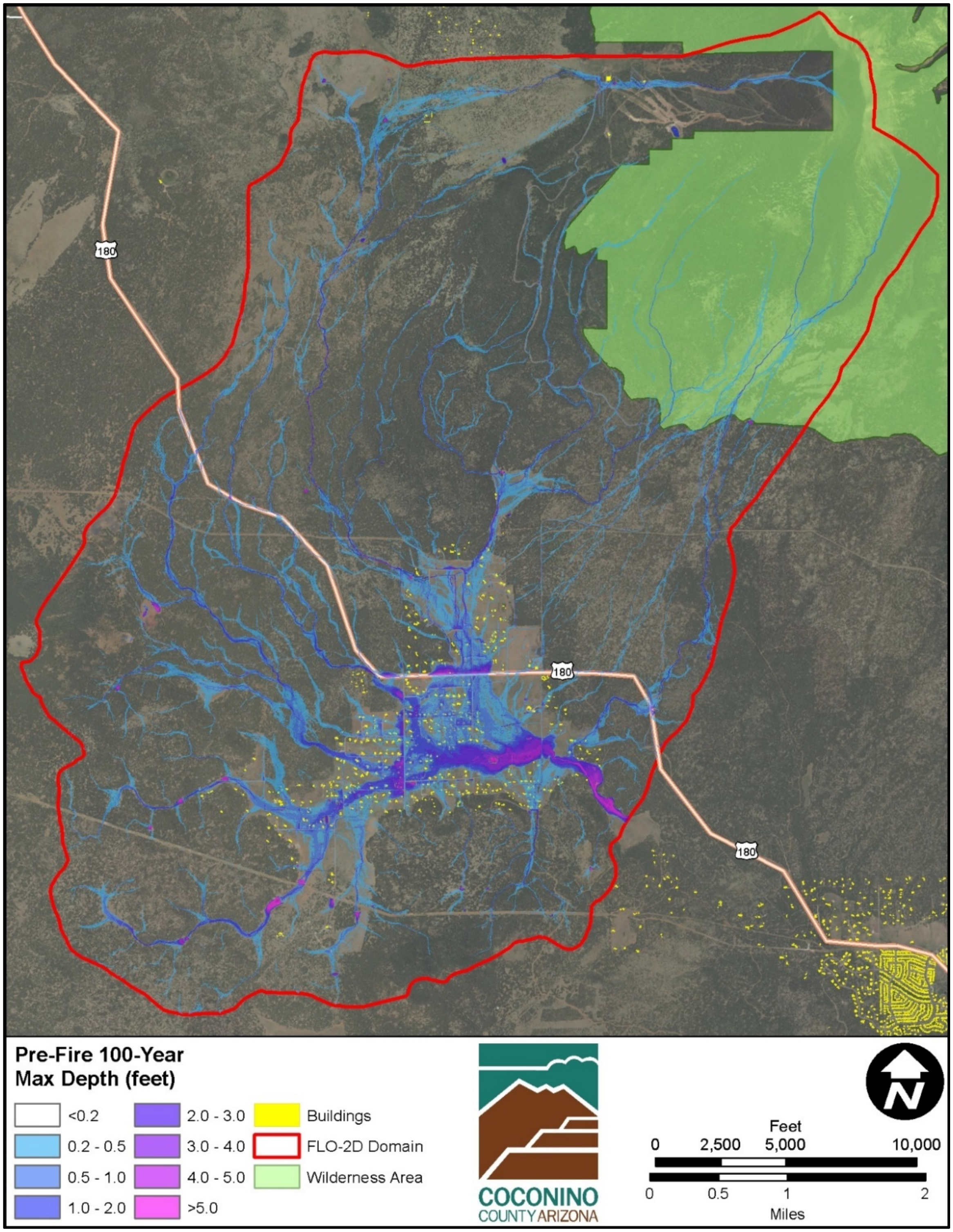

180
180
180
Pre-Fire 100-Year
Max Depth (feet)
<0.2
0.2 - 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 3.0
3.0 - 4.0
4.0 - 5.0
>5.0
Buildings
FLO-2D Domain
Wilderness Area
COCONINO
COUNTY ARIZONA
N
Feet
0
2,500
5,000
10,000
0
0.5
1
2
Miles

Figure 7 - Fort Valley 100-Year Pre-Wildfire Max Flow Depth

3.2 WILDFIRE BURN SEVERITY MODELING

The majority of the Fort Valley pilot area was not included in the USFS fire modeling prepared for the Four Forest Restoration Initiative (4FRI) Environmental Impact Statement (EIS). Therefore, JE Fuller performed fire severity modeling to determine potential runoff curve number changes for a post-wildfire condition. Appendix D contains the full modeling results.

The Fort Valley burn modeling included the following scenarios to reflect potential watershed conditions:

- No Treatment
- Treatment up to 8,200 Feet (No treatment in wilderness areas)
- Treatment (all areas)

Forest treatment refers to thinning and controlled burn efforts used to reduce the density of the trees and the fuel load on the ground. The Fort Valley watershed extends to the top of Agassiz Peak, and includes a large portion of Wilderness Area which has use restrictions that currently prohibit certain types of forest treatment. As such, a fire modeling scenario was included with a fully treated watershed that excluded the wilderness area.

Results from the fire modeling were used to determine curve number adjustments used in the hydrologic modeling described below.

3.3 POST-WILDFIRE DEBRIS-FLOW RISK ASSESSMENT

The Fort Valley debris flow contributing basins were modeled for debris flow probability and volumes based on three burn scenarios. Because debris flows typically initiate in the steep headwaters of basins, which are the areas encompassed by the designated Wilderness, the “Treated All” scenario was included to assess if different responses could be seen between the three forest conditions.

Modeling results show that 15-minute rainfall intensities needed for a 50% probability that a debris flow would occur in the watershed (Table 3, Figure 8) are very low for both treated and untreated conditions. Results show that very minor storms can trigger debris flows in untreated conditions in the Fort Valley study area.

Table 3 - Fort Valley 50% Debris Flow Probability

Modeled Scenario	**15-minute rainfall Intensity (inches/hour)**	**Approximate Storm Event**
Treated All	1.5 – 3.2	1 – 5-year storm event
Treated to 8200’	0.8 – 1.7	<1-year storm event
Untreated	0.8 – 1.4	<1-year storm event

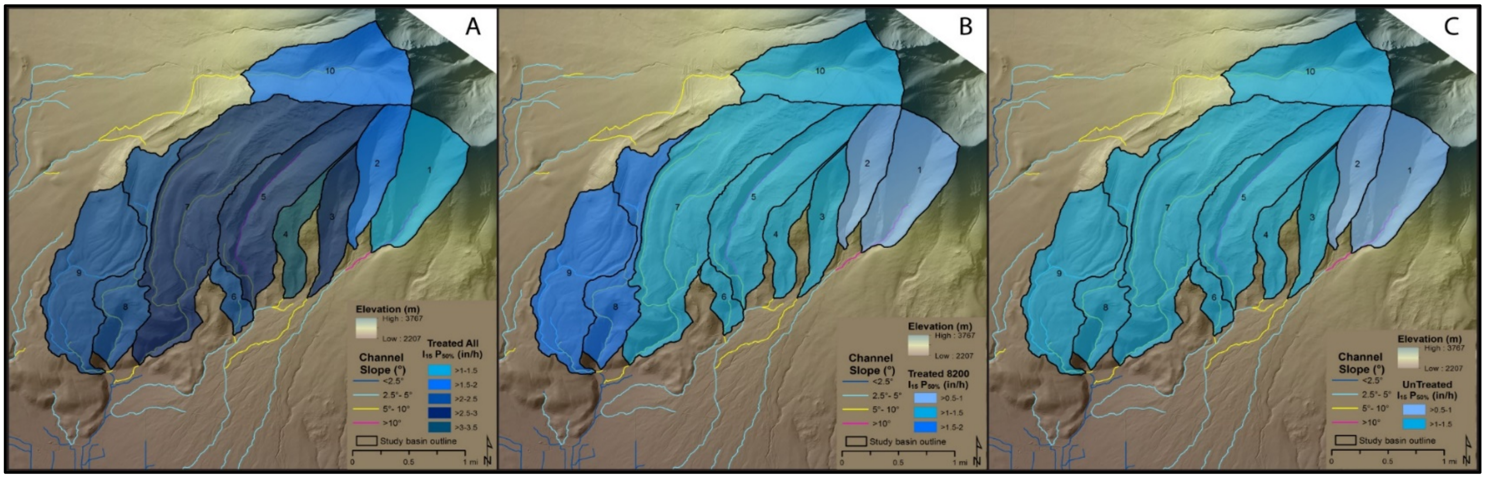


Figure 8 - 15 Min rainfall intensity required for a 50% probability of a debris flow for the TreatedAll (A), Treated8200 (B), and Untreated (C) scenarios.

Potential post-fire debris flow inundation zones were assessed in the Fort Valley watershed using LAHARZ (Figure 9). LAHARZ deposition points were selected based on the channel gradient change at or near the basin mouth, and on loss of channel confinement. Additional deposition points were selected downfan where channels, confined above, lost confinement, and also at the end of debris flow corridors developed during the countywide assessment. A deposition point for the northern portion of the watershed was selected above the Snowbowl Ski Area where the channel sharply turns across the terrace.

Snowbowl Ski Area is located below a bowl on the west side of the San Francisco Peaks and does not flow directly into Fort Valley (Figure 10). While hillslopes in the bowl are steep, channel slopes are 5-10°. LiDAR topography shows terraces along the channel above the ski area. If a post-fire debris flow initiated on the steep hillslopes, there appears to be a good source of transportable material in the terraces that could be eroded and entrained in a flow. Based on observations in the Schultz Fire burned area, debris flows could travel down channels with the existing slopes. The LAHARZ hazard zones show confined and consistent runout patterns for all volumes modeled. If a wildfire burned the slopes above the ski area at high and moderate severity, and a debris flow was initiated during a storm, it is possible that the ski area would be impacted, if not directly by a debris flow, then by flood or hyperconcentrated flows. Depending on where debris flow deposition begins and the runout distance, various facilities at the Snowbowl Ski Area could be impacted including buildings and a cell tower.

LAHARZ model results from basins that flow directly into the meadows of Fort Valley indicate that debris flows are unlikely to directly impact private property or county-identified buildings or critical infrastructure, if deposition begins near points selected in this modeling. While none of the modeled inundation zones approach the developed meadows below, impacts will depend on where deposition actually begins, as well as the characteristics of the flows. High flows across fan surfaces could erode existing channels or cut new channels, providing additional sediment for delivery into the developed areas. In newly incised and confined channels, breach hydrology (debris jams) could occur resulting in temporary dams, dam breaks, and debris flows redeveloping and traveling farther downstream. However, the developed areas will likely be impacted from sediment-laden flood flows and hyperconcentrated flows (flood waters containing high loads of debris, boulders, ash and sediment) that could carry sediment, some of which may be large cobbles or small boulders into the developed areas below. The developed meadows will probably be impacted similarly to those developed areas below the Schultz Fire.

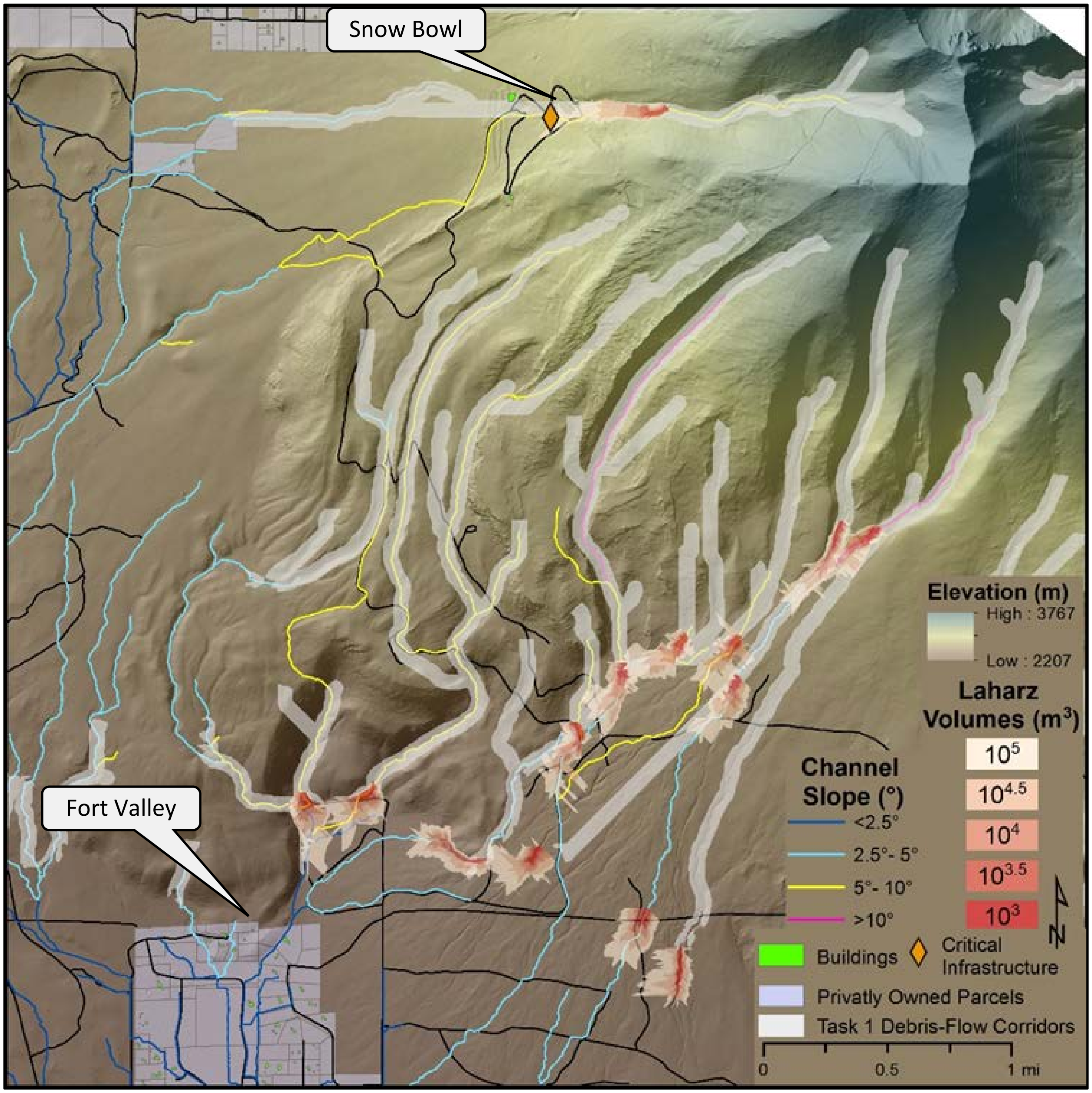

Snow Bowl
Fort Valley
Elevation (m)
High : 3767
Low : 2207
Laharz Volumes (m³)
10⁵
10⁴·⁵
10⁴
10³·⁵
10³
Channel Slope (°)
<2.5°
2.5°- 5°
5°- 10°
>10°
Buildings
Critical Infrastructure
Privatly Owned Parcels
Task 1 Debris-Flow Corridors
0
0.5
1 mi
N

Figure 9 - Fort Valley LAHARZ Model Results

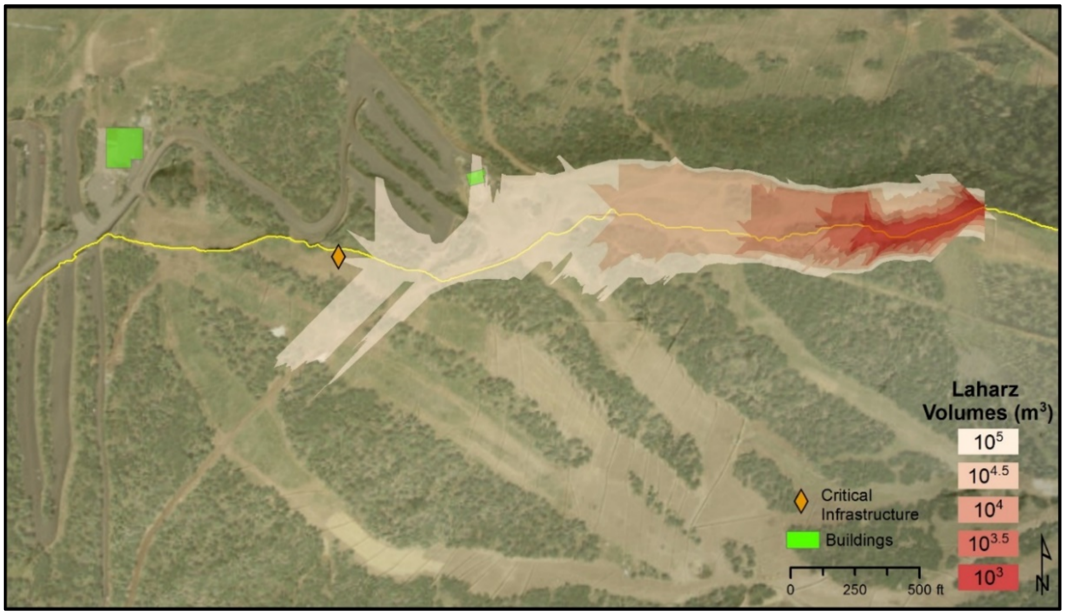

Laharz Volumes (m³)
10⁵
10⁴·⁵
10⁴
10³·⁵
10³
Critical Infrastructure
Buildings
0
250
500 ft
N

Figure 10 - LAHARZ Model Results at Snowbowl

Results from the 1-year storm show a response difference between the three scenarios. An important comparison is the probability that a debris flow will occur during a 1-year storm event (Table 4) and the hazard class ranking of the contributing basins (Figure 11).

Table 4 - Fort Valley Debris-Flow Probability

Modeled Scenario	**Probability of Debris Flow in 1-Year Event**	**Basin Hazard Class Ranking**
Treated All	45% - 77%	Moderate to High
Treated to 8200’	66% - 99%	Moderate to High
Untreated	77% - 99%	High

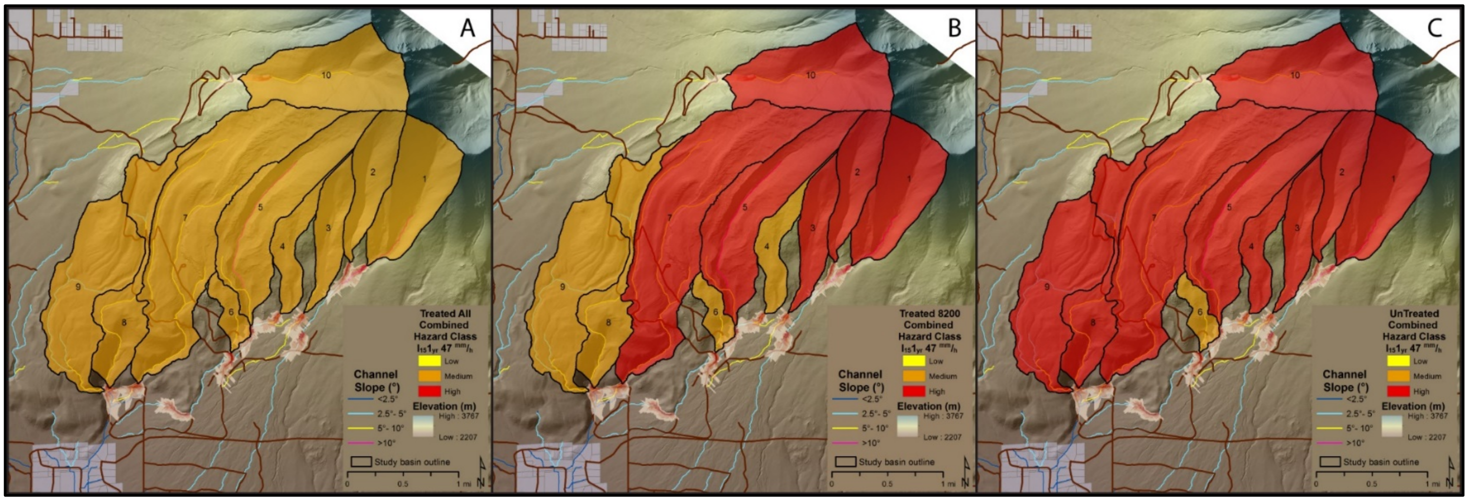

A
B
C
1
2
3
4
5
6
7
8
9
10
Treated All Combined Hazard Class
Treated 8200 Combined Hazard Class
UnTreated Combined Hazard Class
I15 1yr 47 mm/h
Low
Medium
High
Channel Slope (°)
<2.5°
2.5°- 5°
5°- 10°
>10°
Elevation (m)
High : 3767
Low : 2207
Study basin outline
0
0.5
1 mi
N

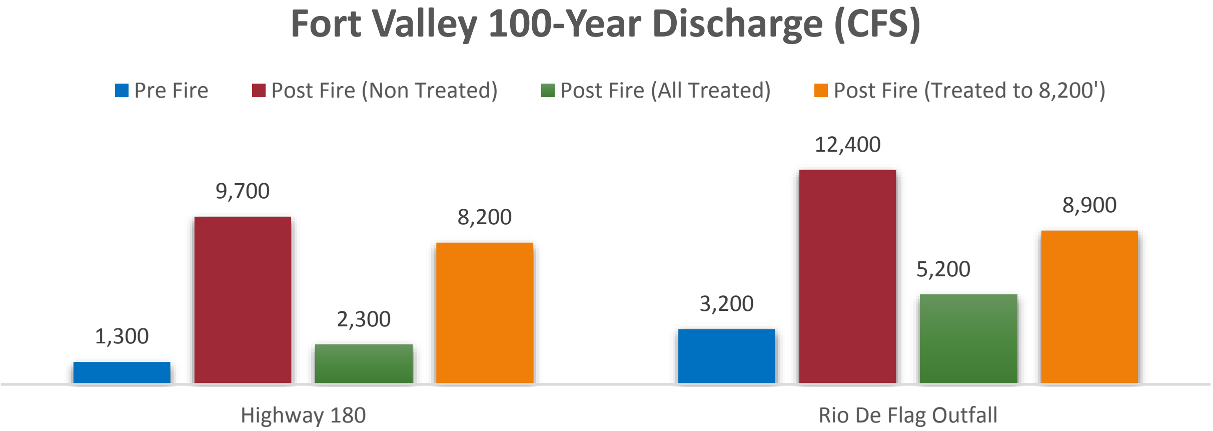
Figure 11 - Combined hazard ranking of the TreatedAll (A), Treated8200 (B), and Untreated (C) scenarios for the I_{15} 1-year storm

Full results of the debris flow modeling are included in Appendix E.

3.4 POST-WILDFIRE FLOOD RISK ASSESSMENT

Post-fire flood impacts and hazards in the Fort Valley pilot watershed were determined for the 2-, 10-, and 100-year events with watershed conditions simulating post-fire conditions. One aspect of this study is to understand and quantify the impact of increased forest health due to forest treatments (thinning, control burns, etc.) on the downstream flood impacts. To accomplish this, the pilot area was modeled with the post-fire watershed condition scenarios described previously.

The 100-year modeling results for the Fort Valley Pilot Area indicate post-fire (no treatment) flows in the Rio de Flag downstream of Fort Valley are up to *4 times* higher than pre-fire discharges. Treating the watershed has the effect of reducing the post-fire discharges by 58% if the entire watershed including the wilderness area is treated, and 28% if the wilderness area is untreated. Discharges originating from Agassiz Peak are of interest because a large portion of the contributing watershed is wilderness. Post-fire (no treatment) discharges that cross Highway 180, originating from Agassiz Peak, are up to 8 *times* higher than pre-fire discharges. If the same watershed is fully treated, post fire discharges may be reduced by 77%. However, the wilderness area is a large portion of the Agassiz Peak contributing watershed and if the area is excluded from treatments (Post-fire, Treatment up to 8,200 feet), post-fire discharges may still be 6 *times* higher than pre-fire conditions, as shown in the graph below.



The Fort Valley flood depth results summarized below demonstrate that watershed treatment has the potential of significantly reducing the number of properties that would be threatened by post-wildfire flooding. No critical facilities shown in the Coconino County Multi-Jurisdictional Hazard Mitigation Plan experience flooding greater than 1 foot deep.

Table 5 - Fort Valley Impacted Buildings – Flooding >1 Foot

Event	Pre-Fire	Post-fire No Treatment	Post-fire Treatment up to 8200’	Post-fire All Treated
2-Year	20	63	48	26
10-Year	33	129	85	47
100-Year	87	222	185	119

Results from the flood modeling are presented in Figure 12 to Figure 14 below. The figures show the resulting areas with flooding depths of greater than 1 foot for the pre-fire and the multiple post-fire scenarios. Flood limits are presented in the following format:

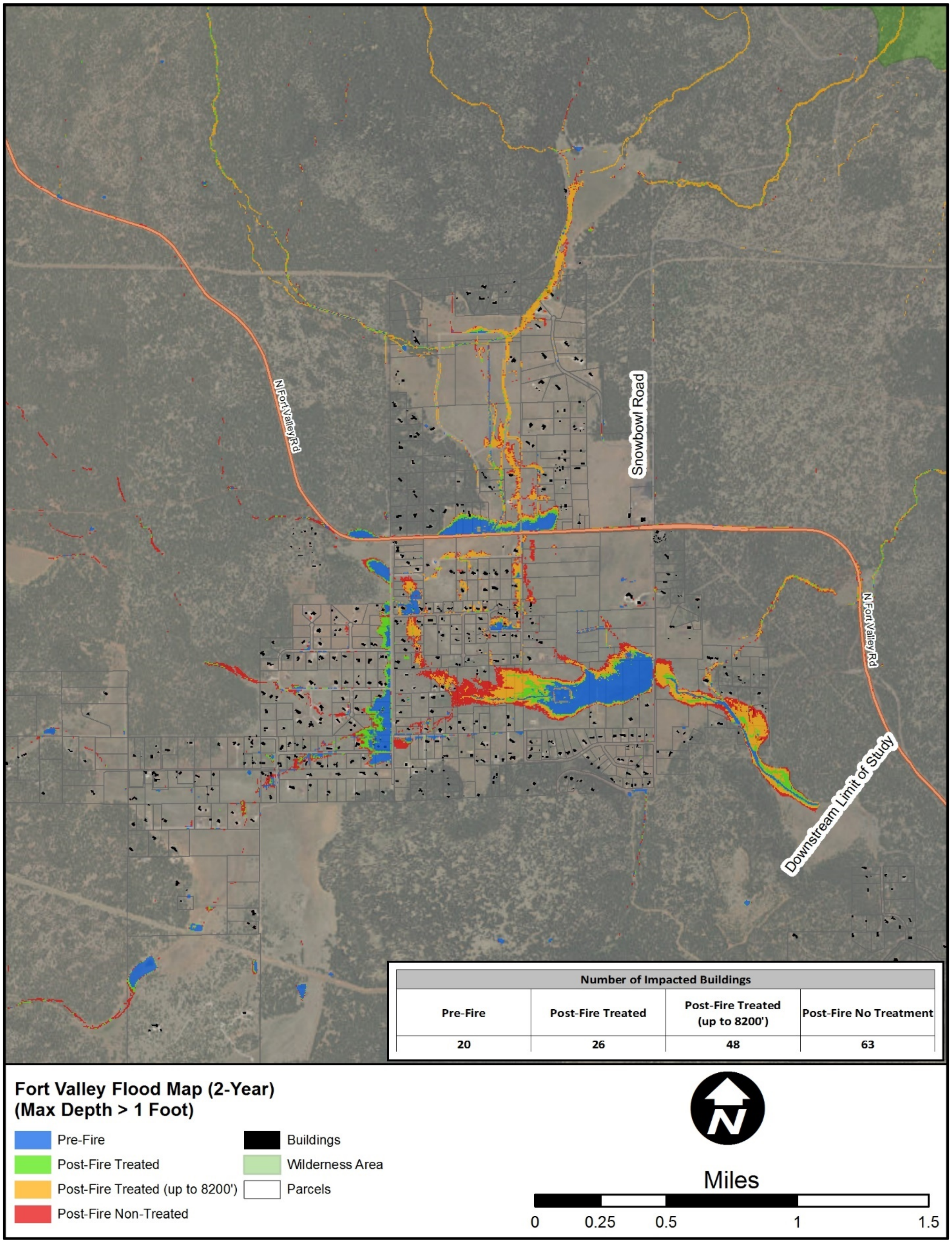
***Pre-Fire* (existing condition)** flooding limits with depths greater than 1 foot. Includes all blue areas on the maps.

Post Fire (All Treated) flooding limits with depths greater than 1 foot. Indicates flooding if a fire burns the entire watershed with all areas treated. Includes all blue and green areas shown on map.

Post Fire (Treated to 8,200' elevation) flooding limits with depths greater than 1 foot. Indicates flooding if a fire burns the entire watershed with all areas treated, excluding the wilderness area. Includes all blue, green, and orange areas shown on map.

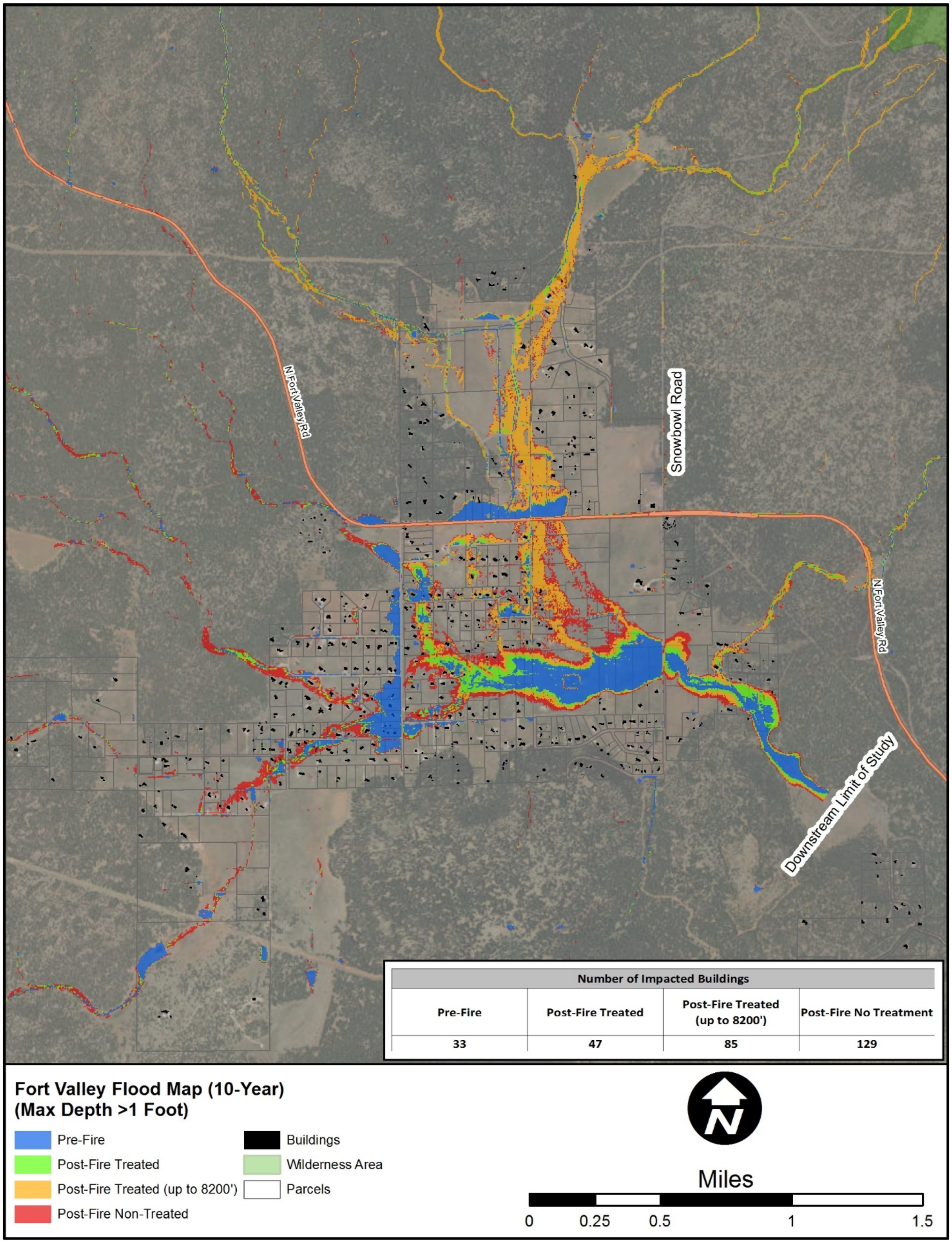
Post Fire (UnTreated) flooding limits with depths greater than 1 foot. Indicates flooding if a fire burns the entire watershed in its current, non-treated condition. Includes all blue, green, orange and red areas shown on map.

Large format maps showing the modeling results are provided in Appendix F.


N Fort Valley Rd
Snowbowl Road
N Fort Valley Rd
Downstream Limit of Study
Fort Valley Flood Map (2-Year)
(Max Depth > 1 Foot)
Pre-Fire
Post-Fire Treated
Post-Fire Treated (up to 8200')
Post-Fire Non-Treated
Buildings
Wilderness Area
Parcels
N
Miles
0
0.25
0.5
1
1.5

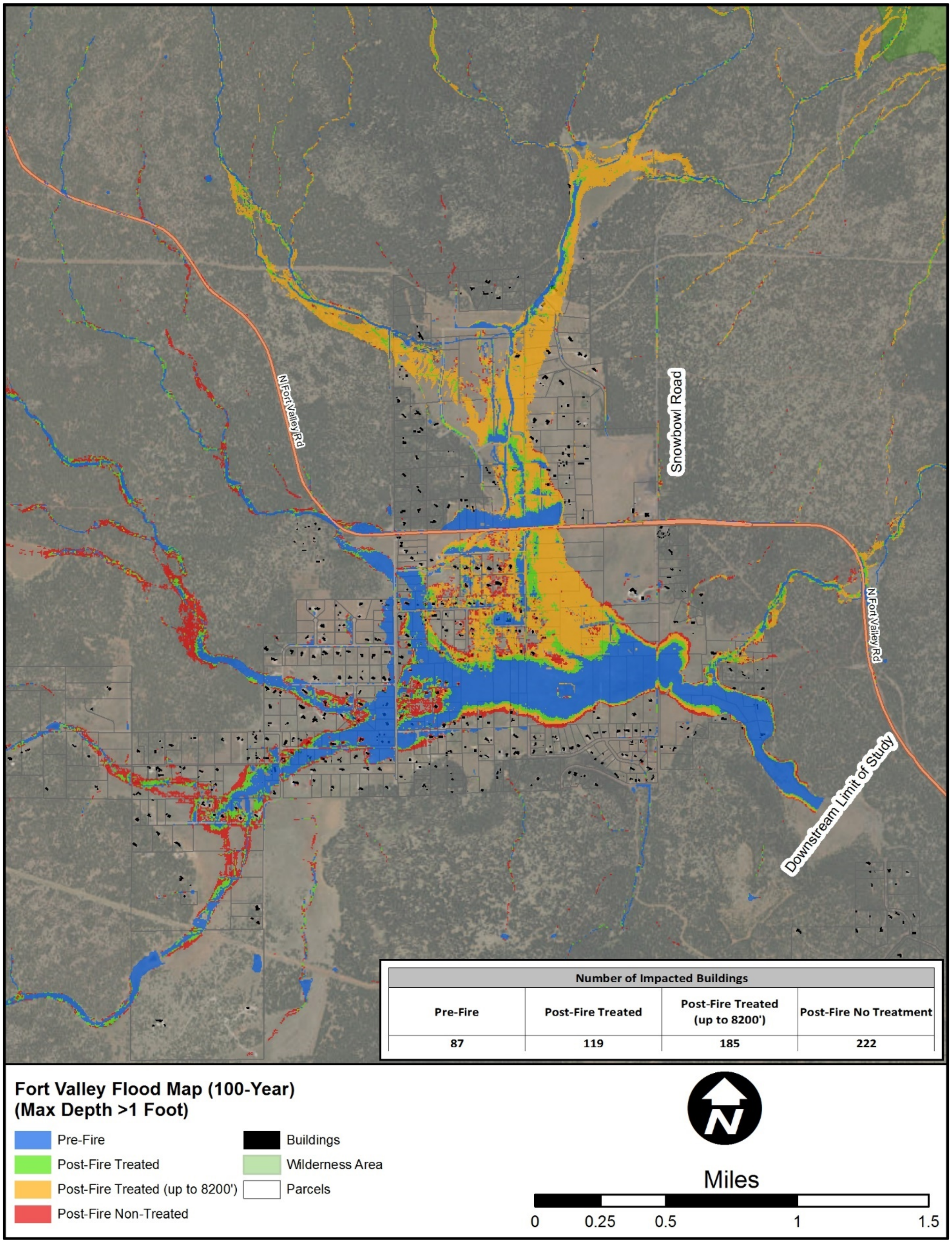
Number of Impacted Buildings			
Pre-Fire	**Post-Fire Treated**	**Post-Fire Treated (up to 8200')**	**Post-Fire No Treatment**
20	26	48	63

Figure 12 - Fort Valley 2-Year Flood Limit Map


N Fort Valley Rd
Snowbowl Road
N Fort Valley Rd
Downstream Limit of Study
Fort Valley Flood Map (10-Year)
(Max Depth >1 Foot)
Pre-Fire
Post-Fire Treated
Post-Fire Treated (up to 8200')
Post-Fire Non-Treated
Buildings
Wilderness Area
Parcels
N
Miles
0
0.25
0.5
1
1.5

Number of Impacted Buildings			
Pre-Fire	Post-Fire Treated	Post-Fire Treated (up to 8200')	Post-Fire No Treatment
33	47	85	129

Figure 13 - Fort Valley 10-Year Flood Limit Map


N Fort Valley Rd
Snowbowl Road
N Fort Valley Rd
Downstream Limit of Study
Fort Valley Flood Map (100-Year)
(Max Depth >1 Foot)
Pre-Fire
Post-Fire Treated
Post-Fire Treated (up to 8200')
Post-Fire Non-Treated
Buildings
Wilderness Area
Parcels
N
Miles
0
0.25
0.5
1
1.5

Number of Impacted Buildings

Pre-Fire	Post-Fire Treated	Post-Fire Treated (up to 8200')	Post-Fire No Treatment
87	119	185	222

Figure 14 - Fort Valley 100-Year Flood Limit

3.5 FORT VALLEY RISK ZONE MAPPING

Findings from the pre- and post-fire flooding and debris flow assessments are summarized in the following non-regulatory risk zone maps. The risk zone maps presented in Figure 15 to Figure 17 indicate the type of hazard (pre-fire flood, post-fire flood, post-fire debris flow, etc.) for the 2-, 10-, and 100-year events. Large format maps are provided in Appendix F.

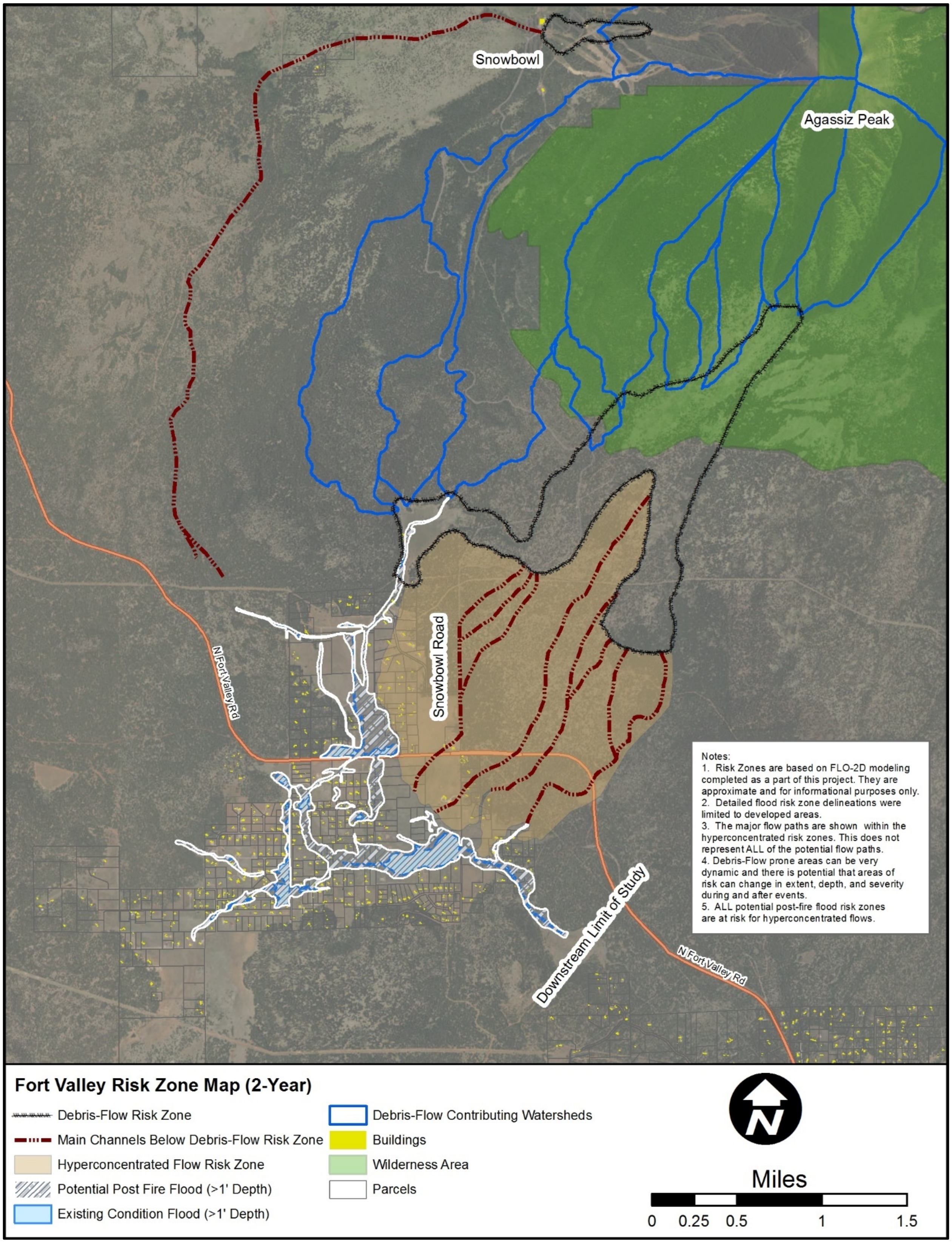
The types of risk zones are summarized below:

Existing Condition Flood – Areas which will potentially be inundated by floodwaters greater than 1 foot in depth if the referenced event occurred in the watershed in its current condition. The shallow flood limits may extend beyond the boundaries presented.

Potential Post-Fire Flood – Areas which will potentially be inundated by floodwaters greater than 1 foot in depth if the referenced event occurred in the watershed in post-fire, untreated conditions (fire burns the watershed in its current condition). The post-fire flood within the Fort Valley study area will most likely consist of hyperconcentrated flood flows (sediment, ash, rocks, debris), similar to the post-Schultz-Fire flooding. Shallow flood limits may extend beyond the boundaries presented.

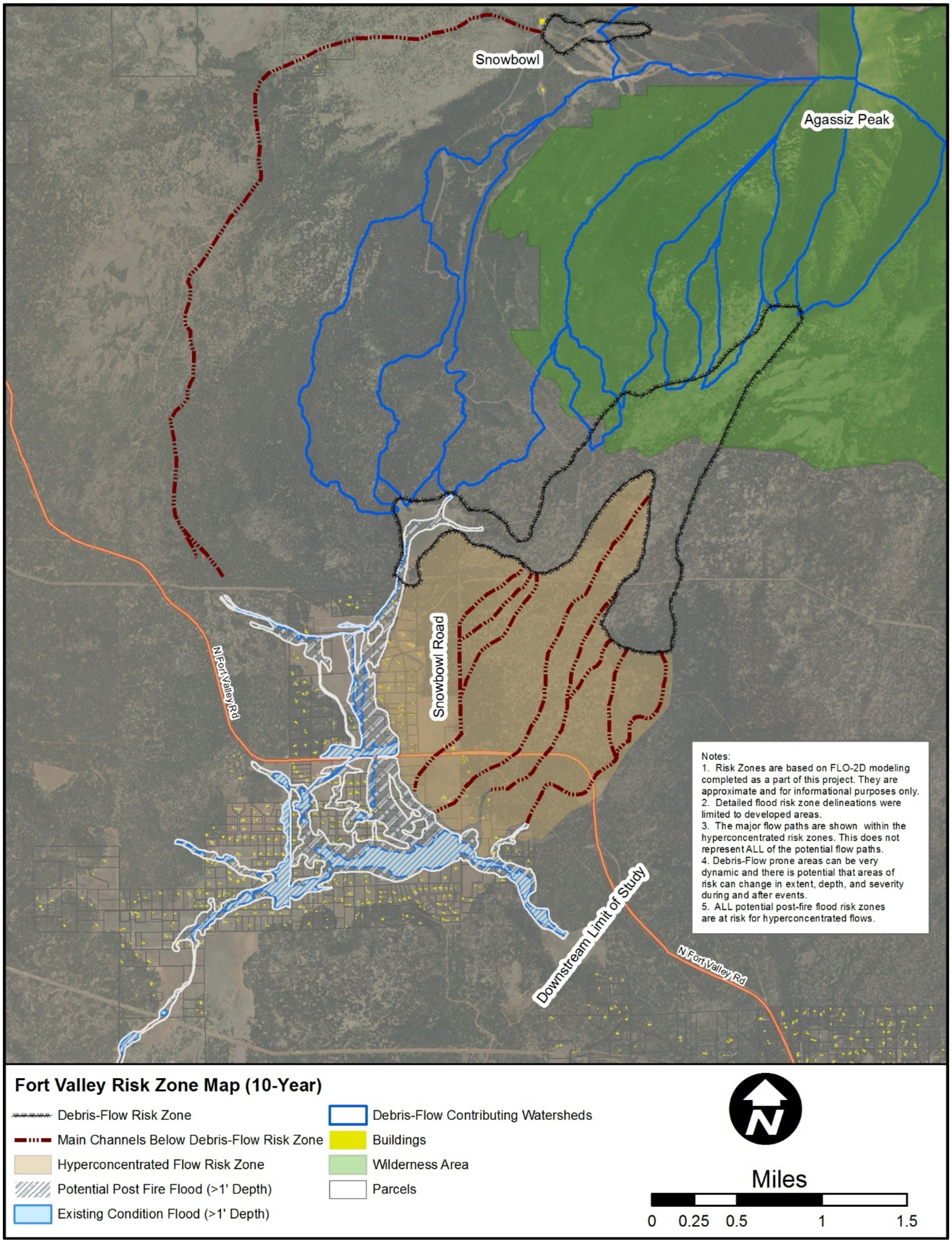
Post-Fire Debris Flow – Areas which may be produce post-fire debris flows. Debris flows erode and scour channels as they travel downslope, releasing sediment for additional transport by hyperconcentrated flows and sediment-laden flood flows. While debris flows may not travel far enough to directly impact houses, infrastructure or other critical facilities, they will indirectly impact these areas of concern by eroding and transporting released sediments via hyperconcentrated and flood flows. Downstream areas will see a significant increase in flooding and sedimentation after wildfires.

Post-Fire Hyperconcentrated Flow – Areas downstream of debris flows which may experience severe erosion, and transport the sediment, water and debris from the base of the potential debris flow to the flood inundation area.


Snowbowl
Agassiz Peak
Snowbowl Road
N Fort Valley Rd
Downstream Limit of Study
N Fort Valley Rd
Fort Valley Risk Zone Map (2-Year)
Debris-Flow Risk Zone
Main Channels Below Debris-Flow Risk Zone
Hyperconcentrated Flow Risk Zone
Potential Post Fire Flood (>1' Depth)
Existing Condition Flood (>1' Depth)
Debris-Flow Contributing Watersheds
Buildings
Wilderness Area
Parcels
N
Miles
0
0.25
0.5
1
1.5

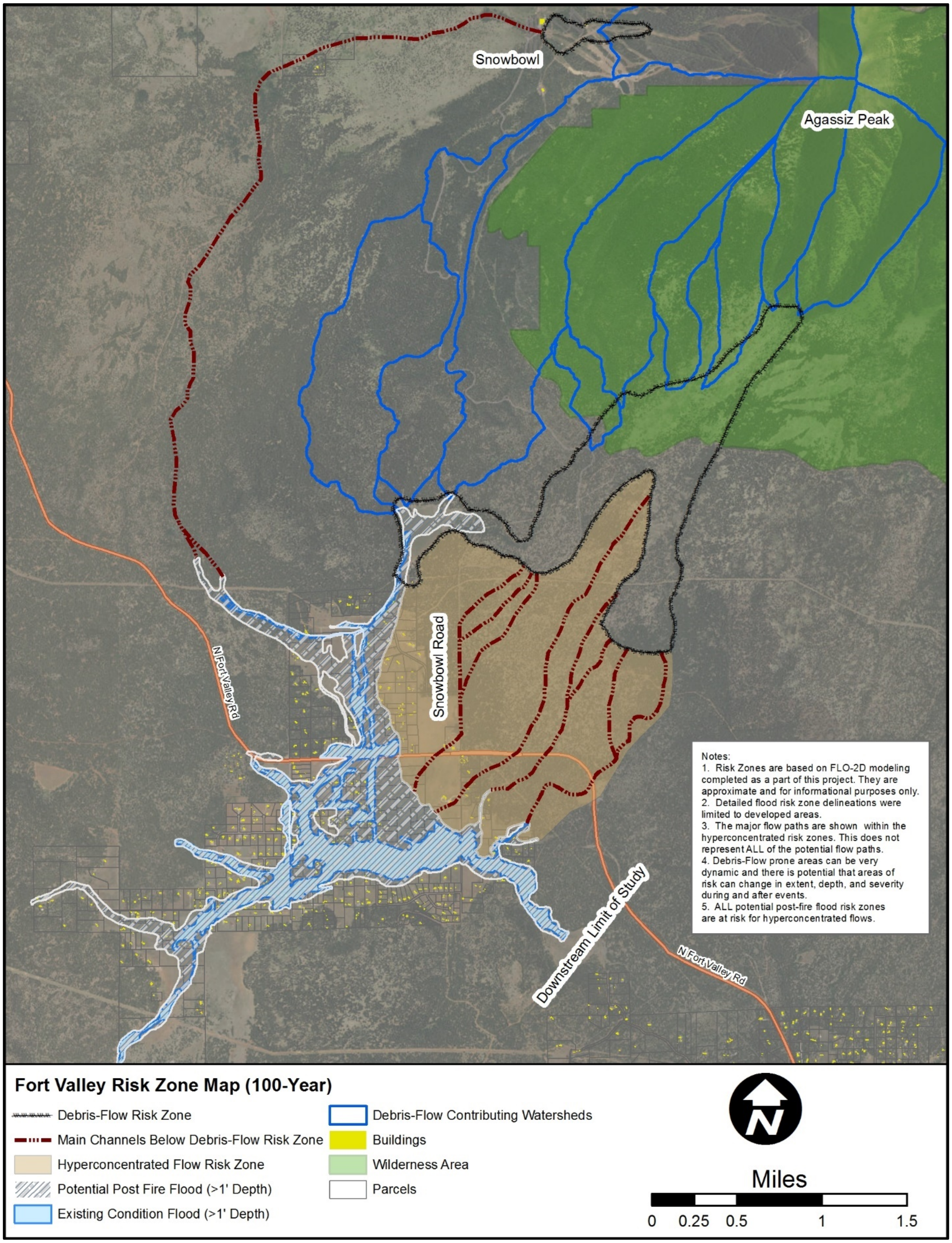
Notes:
1. Risk Zones are based on FLO-2D modeling completed as a part of this project. They are approximate and for informational purposes only.
2. Detailed flood risk zone delineations were limited to developed areas.
3. The major flow paths are shown within the hyperconcentrated risk zones. This does not represent ALL of the potential flow paths.
4. Debris-Flow prone areas can be very dynamic and there is potential that areas of risk can change in extent, depth, and severity during and after events.
5. ALL potential post-fire flood risk zones are at risk for hyperconcentrated flows.

Figure 15 - Fort Valley 2-Year Risk Zone Map


Snowbowl
Agassiz Peak
Snowbowl Road
N Fort Valley Rd
Downstream Limit of Study
N Fort Valley Rd
Fort Valley Risk Zone Map (10-Year)
Debris-Flow Risk Zone
Main Channels Below Debris-Flow Risk Zone
Hyperconcentrated Flow Risk Zone
Potential Post Fire Flood (>1' Depth)
Existing Condition Flood (>1' Depth)
Debris-Flow Contributing Watersheds
Buildings
Wilderness Area
Parcels
N
Miles
0
0.25
0.5
1
1.5

Notes:
1. Risk Zones are based on FLO-2D modeling completed as a part of this project. They are approximate and for informational purposes only.
2. Detailed flood risk zone delineations were limited to developed areas.
3. The major flow paths are shown within the hyperconcentrated risk zones. This does not represent ALL of the potential flow paths.
4. Debris-Flow prone areas can be very dynamic and there is potential that areas of risk can change in extent, depth, and severity during and after events.
5. ALL potential post-fire flood risk zones are at risk for hyperconcentrated flows.

Figure 16 - Fort Valley 10-Year Risk Zone Map


Snowbowl
Agassiz Peak
Snowbowl Road
N Fort Valley Rd
Downstream Limit of Study
N Fort Valley Rd
Fort Valley Risk Zone Map (100-Year)
Debris-Flow Risk Zone
Main Channels Below Debris-Flow Risk Zone
Hyperconcentrated Flow Risk Zone
Potential Post Fire Flood (>1' Depth)
Existing Condition Flood (>1' Depth)
Debris-Flow Contributing Watersheds
Buildings
Wilderness Area
Parcels
N
Miles
0
0.25
0.5
1
1.5

Notes:
1. Risk Zones are based on FLO-2D modeling completed as a part of this project. They are approximate and for informational purposes only.
2. Detailed flood risk zone delineations were limited to developed areas.
3. The major flow paths are shown within the hyperconcentrated risk zones. This does not represent ALL of the potential flow paths.
4. Debris-Flow prone areas can be very dynamic and there is potential that areas of risk can change in extent, depth, and severity during and after events.
5. ALL potential post-fire flood risk zones are at risk for hyperconcentrated flows.

Figure 17 - Fort Valley 100-Year Risk Zone Map

4 WILLIAMS RISK ASSESSMENT

4.1 PRE-WILDFIRE DEBRIS-FLOW AND FLOODING ASSESSMENT

The Williams Pilot Area was studied to understand the pre- and post-wildfire risks associated with flooding and debris flows. To accomplish a full comparison of pre-and post-risks, the following watershed conditions were studied and are described in the following sections.

- Pre-Fire (unburned)
- Post-Fire, No Treatment
- Post-Fire, Treated

4.1.1 Assessment of Past Debris-Flow Occurrence

The goal of this phase of the study was to assess if the watersheds originating on Bill Williams Mountain could experience debris flows after wildfires. To do this, a reconnaissance field investigation was conducted in the main Cataract Creek drainage leading towards the City Dam Reservoir.

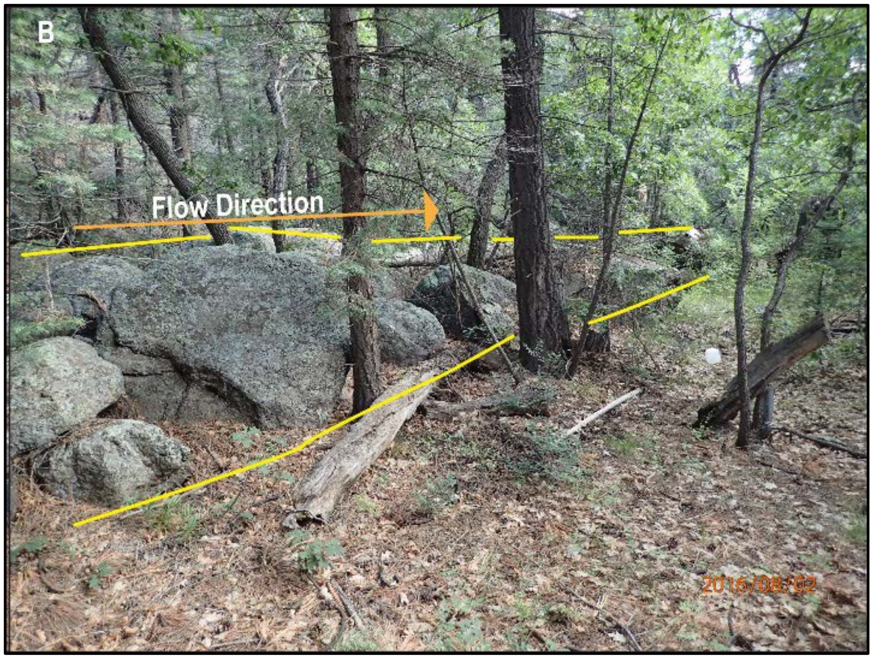


Figure 18 - Linear boulder deposits

Debris flow deposits were documented in the Williams pilot study area in the main Cataract Creek Channel (Figure 18 and Figure 19). The deposits appear to agree well with the assumptions made in countywide assessment. The presence of debris flow-like boulder deposits, however, strongly suggests that debris flows occurred in the past and can occur in the future. Importantly, all the channel sections visited had stored sediment available for transport should a debris flow initiate higher in the watershed.

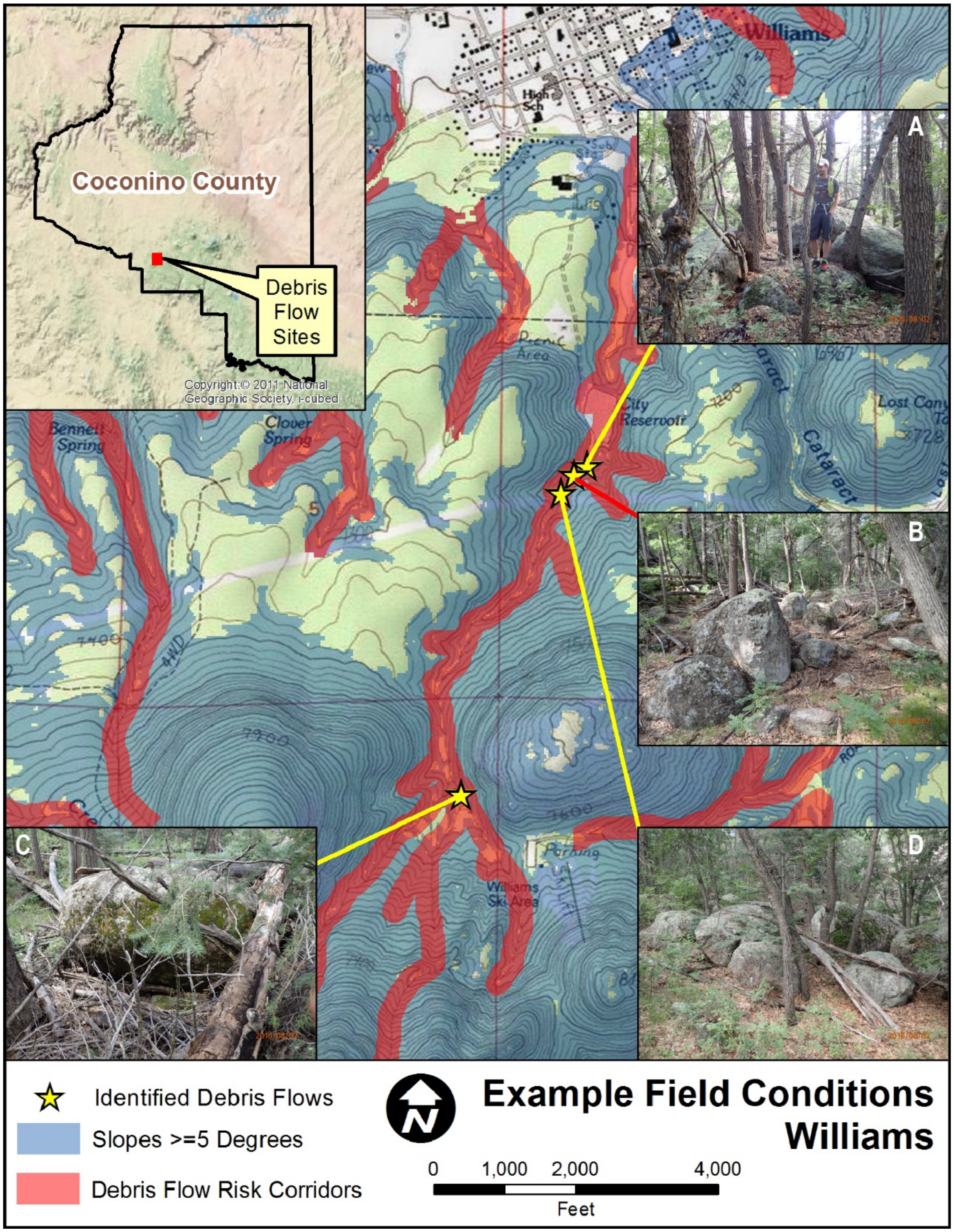

Coconino County
Debris Flow Sites
Copyright:© 2011 National Geographic Society, i-cubed
Williams
High Sch
Picnic Area
City Reservoir
Cataract
Lost Cany
Bennett Spring
Clover Spring
7400
7900
7600
4WD
Parking
Williams Ski Area
A
B
C
D
Identified Debris Flows
Slopes >=5 Degrees
Debris Flow Risk Corridors
N
Example Field Conditions Williams
0
1,000
2,000
4,000
Feet

Figure 19 - Williams Pre-Wildfire Field Conditions

4.1.2 Pre-Wildfire Flooding Assessment

Pre-wildfire flooding risk was estimated for the 2-, 10-, and 100-year events in the Williams study area. The full results are not presented in this report, but a detailed description of the pre-fire flooding assessment is provided in Appendix B. Figure 20 shows the pre-wildfire 100-year depth results.

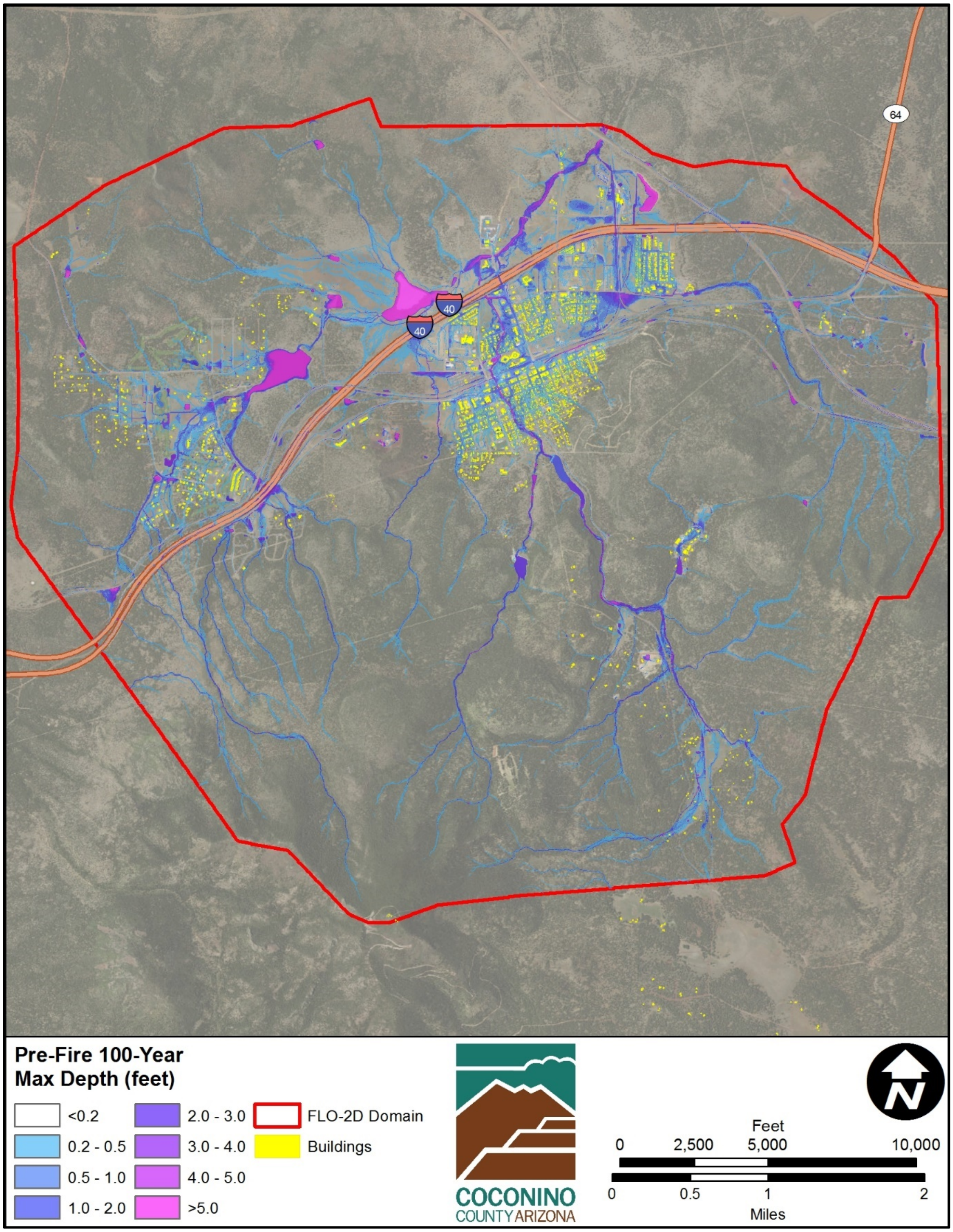

64
40
40
Pre-Fire 100-Year Max Depth (feet)
<0.2
0.2 - 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 3.0
3.0 - 4.0
4.0 - 5.0
>5.0
FLO-2D Domain
Buildings
COCONINO COUNTY ARIZONA
Feet
0
2,500
5,000
10,000
0
0.5
1
2
Miles
N

Figure 20 - Williams 100-Year Pre-Wildfire Max Flow Depth

4.2 WILDFIRE BURN SEVERITY MODELING

The majority of the Williams pilot area was included in the USFS fire modeling prepared for the Bill Williams Mountain Restoration Project. Fire severity modeling completed for the USFS Environmental Impact Statement were used in this study. Appendix D contains a description of the USFS modeling.

The Bill Williams Mountain burn modeling included two scenarios.

- No Treatment
- Treatment (all areas)

Treatment refers to thinning and control burn efforts used to reduce the density of the trees and the fuel load on the ground. Results from the fire modeling were used to determine curve number adjustments included in the hydrologic modeling.

4.3 POST-WILDFIRE DEBRIS-FLOW RISK ASSESSMENT

The Williams debris flow contributing basins were modeled for debris flow probability and volumes based on three burn scenarios. Modeling results show that 15-minute rainfall intensities needed for a 50% probability that a debris flow would occur in the watershed (Table 6, Figure 21) are very low for both treated and untreated conditions. Results show that very minor storms can trigger debris flows in untreated conditions.

Table 6 - Williams 50% Debris Flow Probability

Modeled Scenario	**15-minute rainfall Intensity (inches/hour)**	**Approximate Storm Event**
Treated	1.0 – 2.0	≤1-year storm event
No Treatment	0.4 – 1.6	<1-year storm event

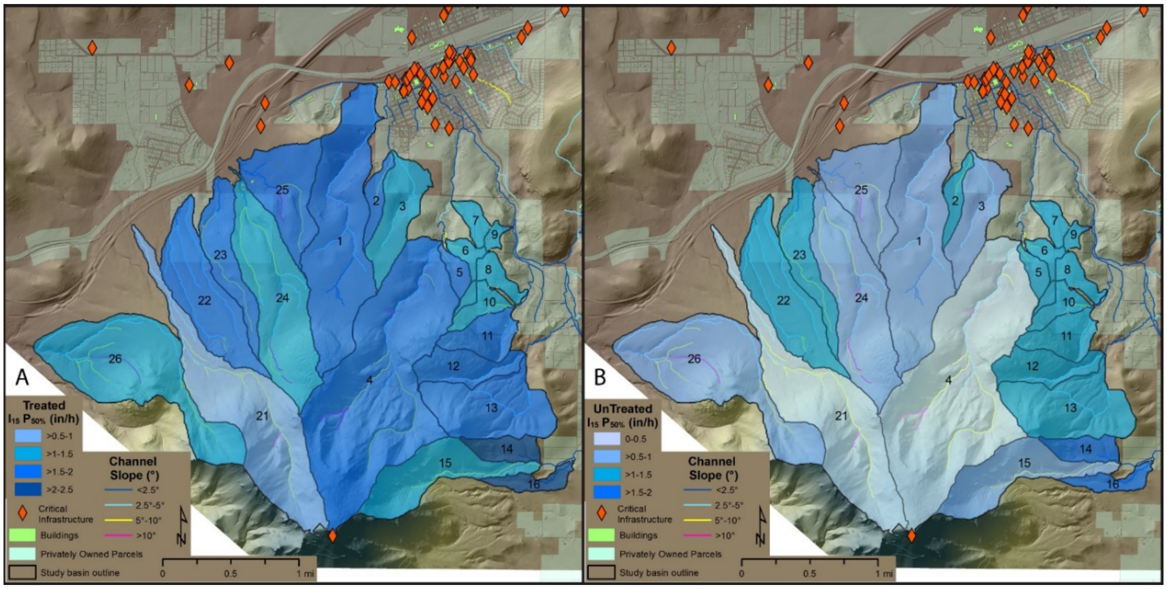

A
Treated
I_{15} $P_{50\%}$ (in/h)
>0.5-1
>1-1.5
>1.5-2
>2-2.5
B
UnTreated
I_{15} $P_{50\%}$ (in/h)
0-0.5
>0.5-1
>1-1.5
>1.5-2
Channel Slope (°)
<2.5°
2.5°-5°
5°-10°
>10°
Critical Infrastructure
Buildings
Privately Owned Parcels
Study basin outline
0
0.5
1 mi
N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
21
22
23
24
25
26

Figure 21 - 15 Min rainfall intensity required for a 50% probability of a debris flow for the Treated (A) and Untreated (B) scenarios.

Potential post-fire debris flow inundation zones were assessed in the Williams pilot area using LAHARZ (Figure 22). LAHARZ deposition points were selected based on the channel gradient change at or near the basin mouth, loss of channel confinement, and at the end of debris flow corridors developed during the countywide assessment.

LAHARZ model results from the Williams study area indicate that debris flows could directly or indirectly impact developed areas. Some basins are relatively small with lower gradient channels so debris flow volumes and runout distances are likely to be smaller, however they flow directly into developed areas. Many of these basins have a combined hazard ranking of medium, even for larger storms, due to their predicted limited volumes. They pose a risk, however, simply because of their proximity to developed areas. Adjacent and downstream areas could also be impacted by subsequent sediment-laden floods and hyperconcentrated flows that could carry large cobbles and small boulders. Downstream developed areas will probably be impacted similarly to the developed areas below the Schultz Fire.

There is a strong likelihood that post-wildfire debris flows could impact City Dam Reservoir. In addition to the main tributary of Cataract Creek that flows into City Dam Reservoir, there are several small side tributaries near the reservoir that could contribute significant sediment volumes during post-fire floods or debris flows above the reservoir. While it is unlikely there will be sufficient debris flow volume to overfill City Dam Reservoir (capacity ~$10^{5.5}$ m^3), the drinking water supply for Williams could be compromised and extremely expensive to mitigate[12].

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[12] Horner et al., 2016

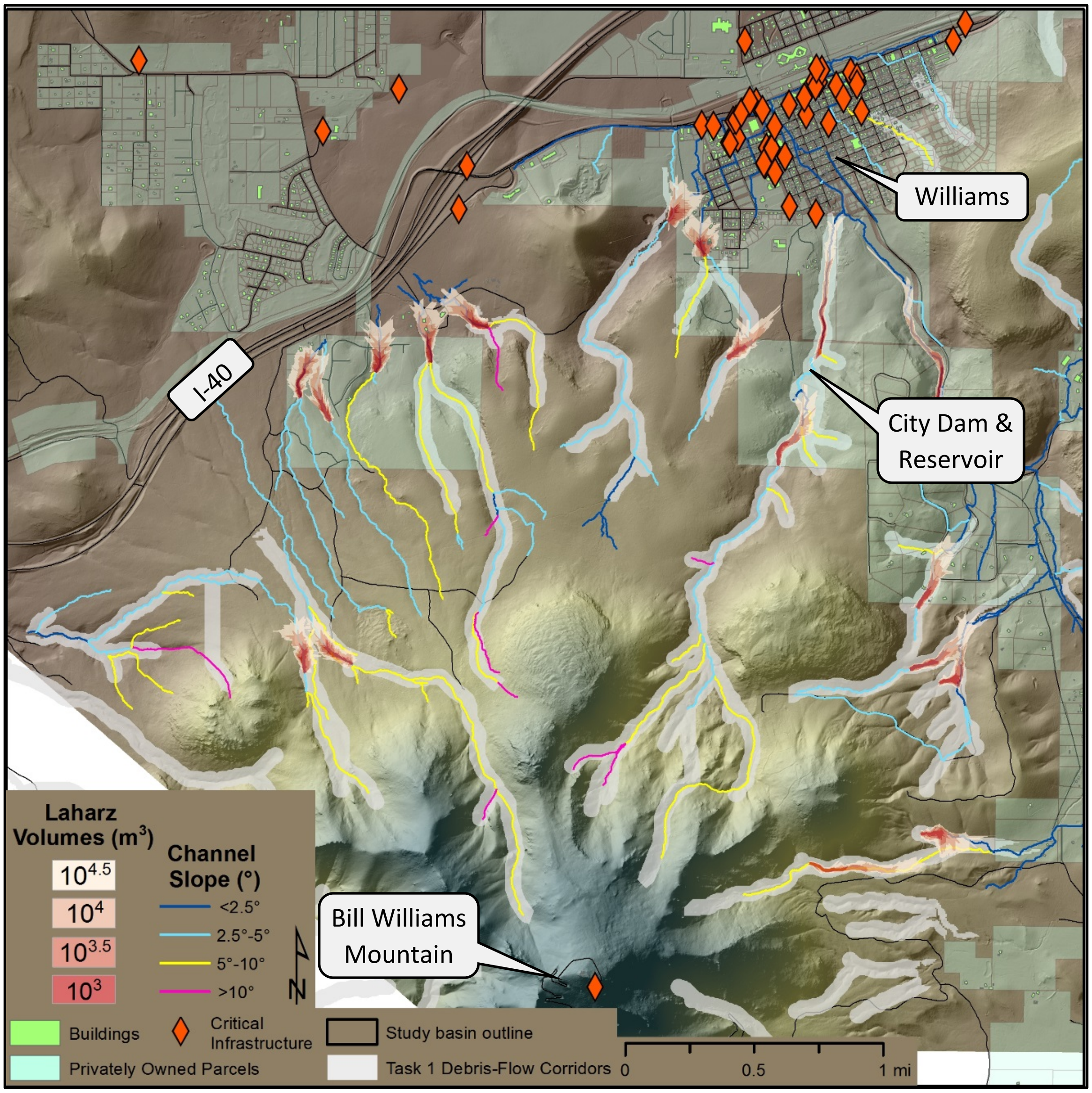

Williams
City Dam & Reservoir
I-40
Bill Williams Mountain
Laharz Volumes (m³)
10^4.5
10^4
10^3.5
10^3
Channel Slope (°)
<2.5°
2.5°-5°
5°-10°
>10°
N
Buildings
Critical Infrastructure
Study basin outline
Privately Owned Parcels
Task 1 Debris-Flow Corridors
0
0.5
1 mi

Figure 22 - LAHARZ Model Results for the Williams Pilot Area

Results from the 1-year storm show a response difference between the three scenarios. An important comparison is the probability that a debris flow will occur during a 1-year storm event (Table 7) and the hazard class ranking of the contributing basins (Figure 23).

Table 7 - Williams Debris Flow Probability

Modeled Scenario	Probability of Debris Flow in 1-Year Event	Basin Hazard Class Ranking
Treated	38% - 94%	Low to High
No Treatment	66% - 99%	Moderate to High

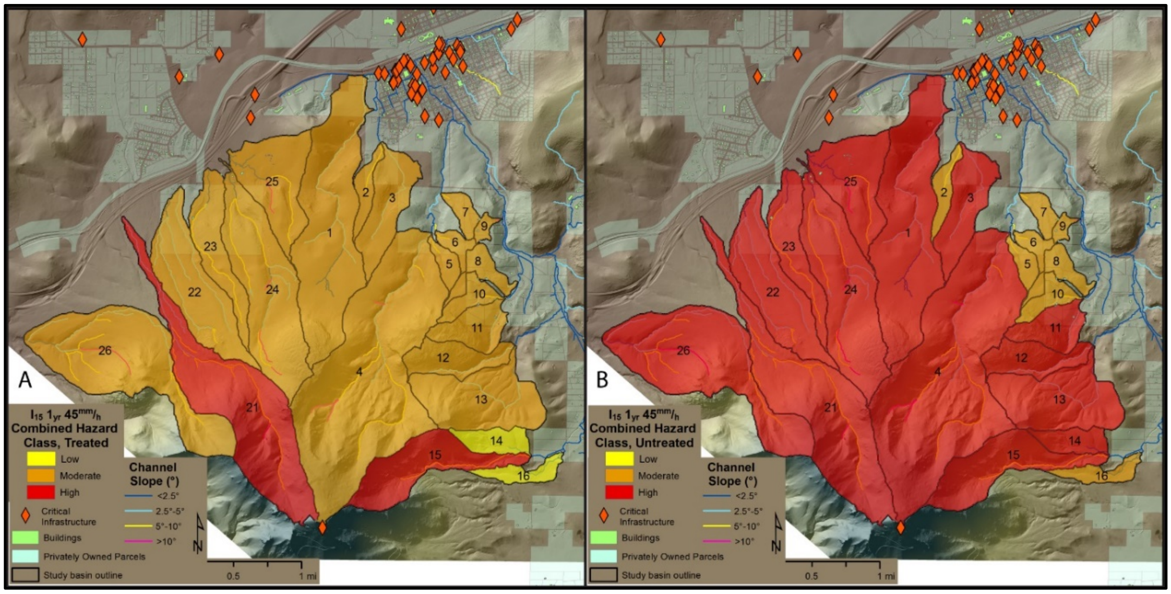

A
I15 1yr 45mm/h
Combined Hazard Class, Treated
Low
Moderate
High
Critical Infrastructure
Buildings
Privately Owned Parcels
Study basin outline
Channel Slope (°)
<2.5°
2.5°-5°
5°-10°
>10°
0.5
1 mi
B
I15 1yr 45mm/h
Combined Hazard Class, Untreated
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
21
22
23
24
25
26

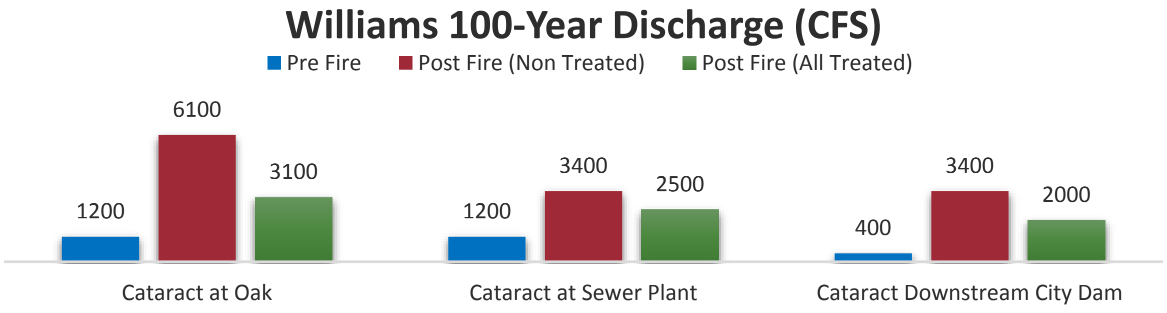
Figure 23 - Combined hazard ranking of the treated (A) and untreated (B) scenarios for the I_{15} 1-year storm.

Full modeling results are provided in Appendix E.

4.4 POST-WILDFIRE FLOOD RISK ASSESSMENT

Post-fire flood impacts and hazards in the Williams pilot area were determined for the 2-, 10-, and 100-year events for post-fire watershed conditions. One aspect of this study is to understand and quantify the impact of increased forest health due to forest treatments (thinning, control burns, etc.) on the downstream flood impacts. To accomplish this, the pilot area was modeled with several post-fire watershed condition scenarios.

The 100-year modeling results for the Williams Pilot Area indicate post-fire (no treatment) flows in Cataract Creek at the south end of Williams (Oak Street) increase by up to *5 times* the pre-fire discharges. Treating the watershed has the effect of reducing the post-fire discharges by 49%. Cataract Creek Discharges near the sewer treatment plant increase by up to *3 times* the pre-fire discharges. Treating the watershed has the effect of reducing the post-fire discharges by 27%. Some of the upper watersheds on Bill Williams Mountain that have the potential to burn the most severely experience significant increases in flows. Directly downstream of the City Dam, post-fire (no treatment) flows increase by up to 8 times the pre-fire discharges. Treating the watershed has the effect of reducing the post-fire discharges by 40%, as shown in the graph below.



The Williams area flood depth results summarized below demonstrate that watershed treatment has the potential of significantly reducing the number of properties that would be threatened by post-wildfire flooding.

Table 8 - Williams Impacted Buildings – Flooding >1 Foot

Event	Pre-Fire	Post-fire No Treatment	Post-fire All Treated
2-Year	26	117	34
10-Year	41	268	105
100-Year	147	515	318

Many critical facilities in the Williams area listed in the Coconino County Multi-Jurisdictional Hazard Mitigation Plan would be impacted by post-fire flooding.

Table 9 - Williams Impacted Critical Facilities – Flooding > 1 Foot

Event	Pre-Fire	Post-fire No Treatment	Post-fire Treated
2-Year	1	4	1
10-Year	1	7	4
100-Year	4	14	8

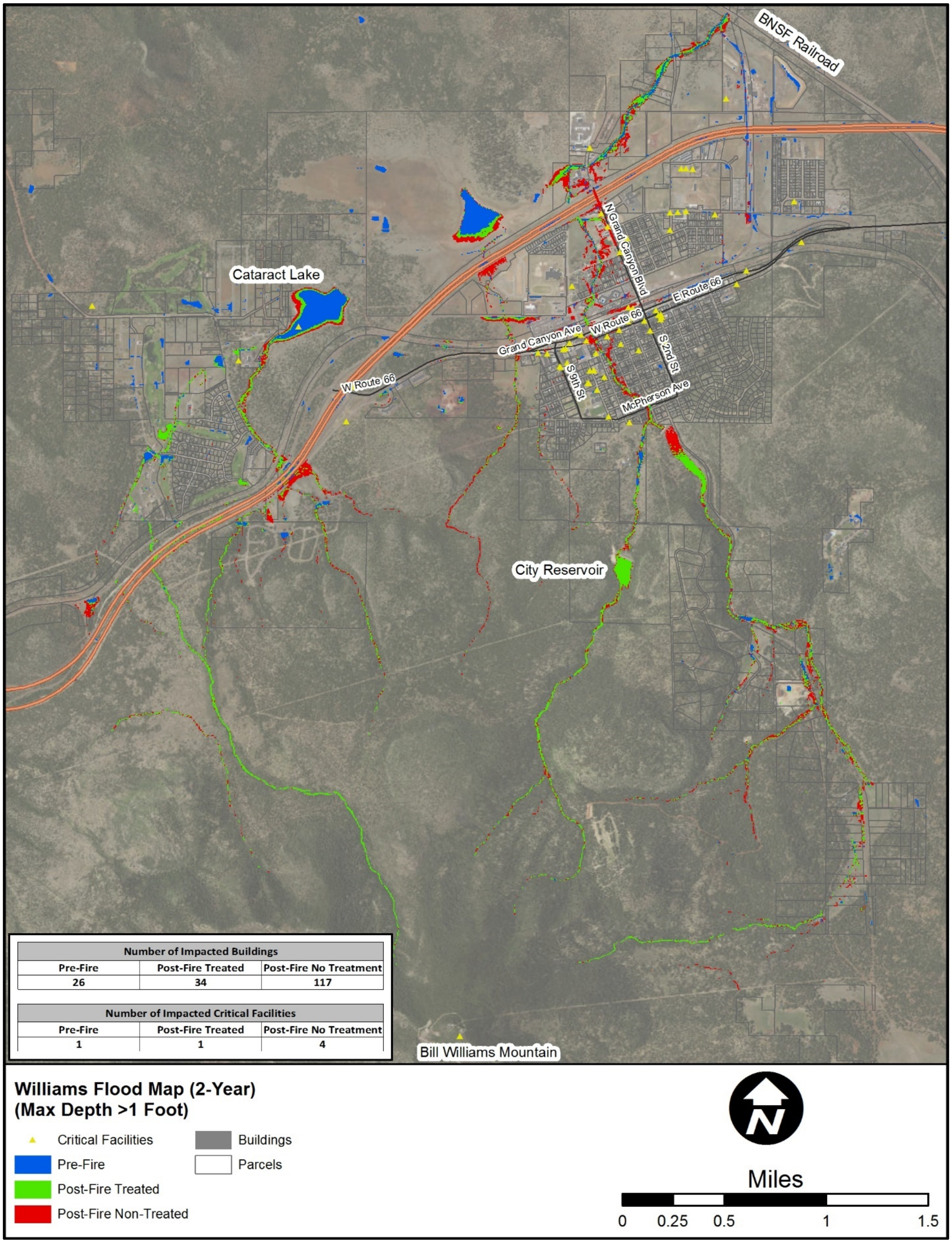
Results from the flood modeling are presented in Figure 24 to Figure 26 below. The figures show the resulting areas with flooding depths of greater than 1 foot for the pre-fire and the multiple post-fire scenarios. Flood limits are presented in the following format:

***Pre-Fire* (existing condition)** flooding limits with depths greater than 1 foot. Includes all blue areas on the maps.

Post Fire (Treated) flooding limits with depths greater than 1 foot. Indicates flooding if a fire burns the entire watershed with all areas treated. Includes all blue and green areas shown on map.

Post Fire (Non Treated) flooding limits with depths greater than 1 foot. Indicates flooding if a fire burns the entire watershed in its current, non-treated condition. Includes all blue, green, and red areas.

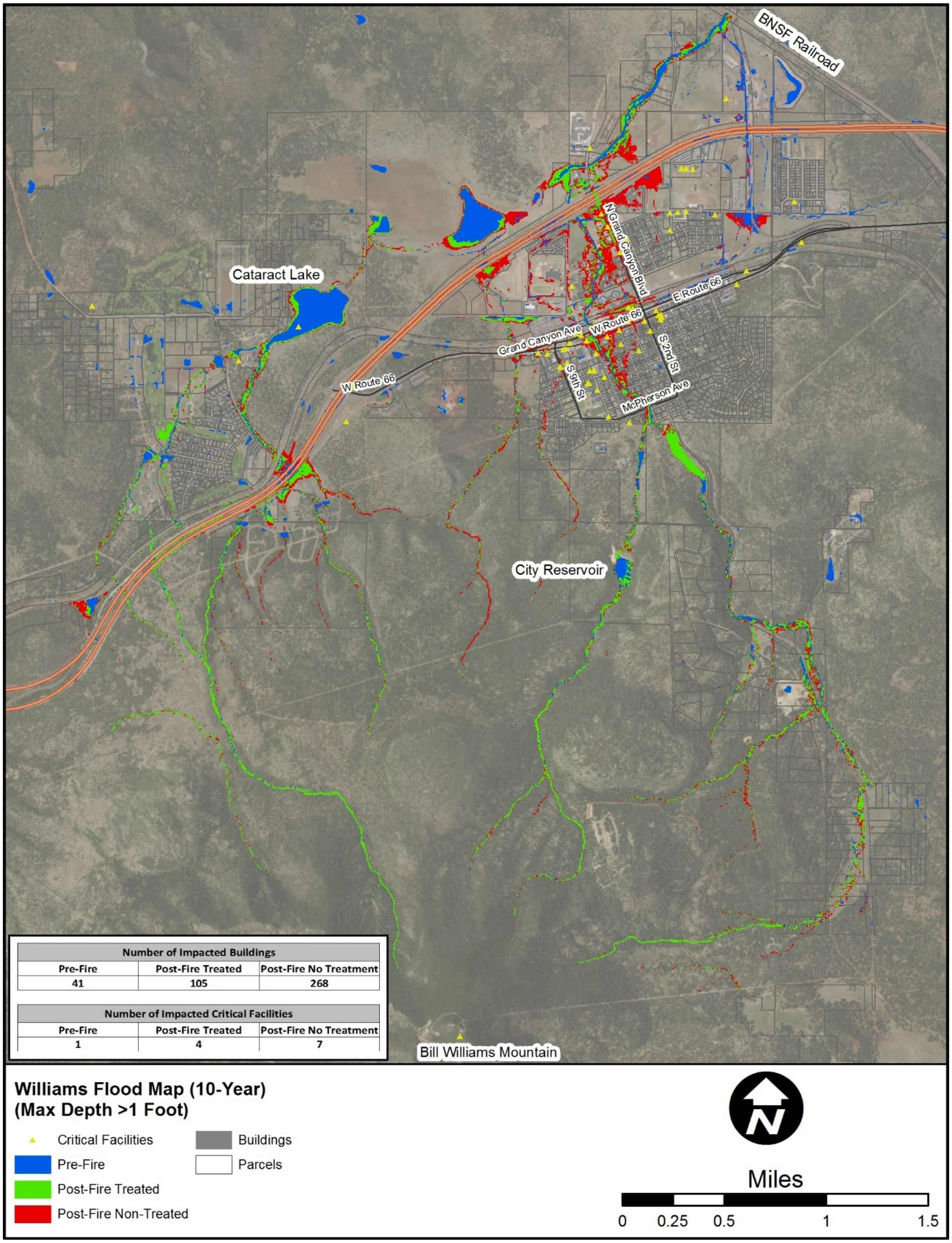
Large format maps are provided in Appendix F.


BNSF Railroad
Cataract Lake
N Grand Canyon Blvd
E Route 66
W Route 66
Grand Canyon Ave
S 2nd St
S 9th St
McPherson Ave
W Route 66
City Reservoir
Bill Williams Mountain
Williams Flood Map (2-Year)
(Max Depth >1 Foot)
Critical Facilities
Pre-Fire
Post-Fire Treated
Post-Fire Non-Treated
Buildings
Parcels
N
Miles
0
0.25
0.5
1
1.5

Number of Impacted Buildings		
Pre-Fire	**Post-Fire Treated**	**Post-Fire No Treatment**
26	34	117

Number of Impacted Critical Facilities		
Pre-Fire	**Post-Fire Treated**	**Post-Fire No Treatment**
1	1	4

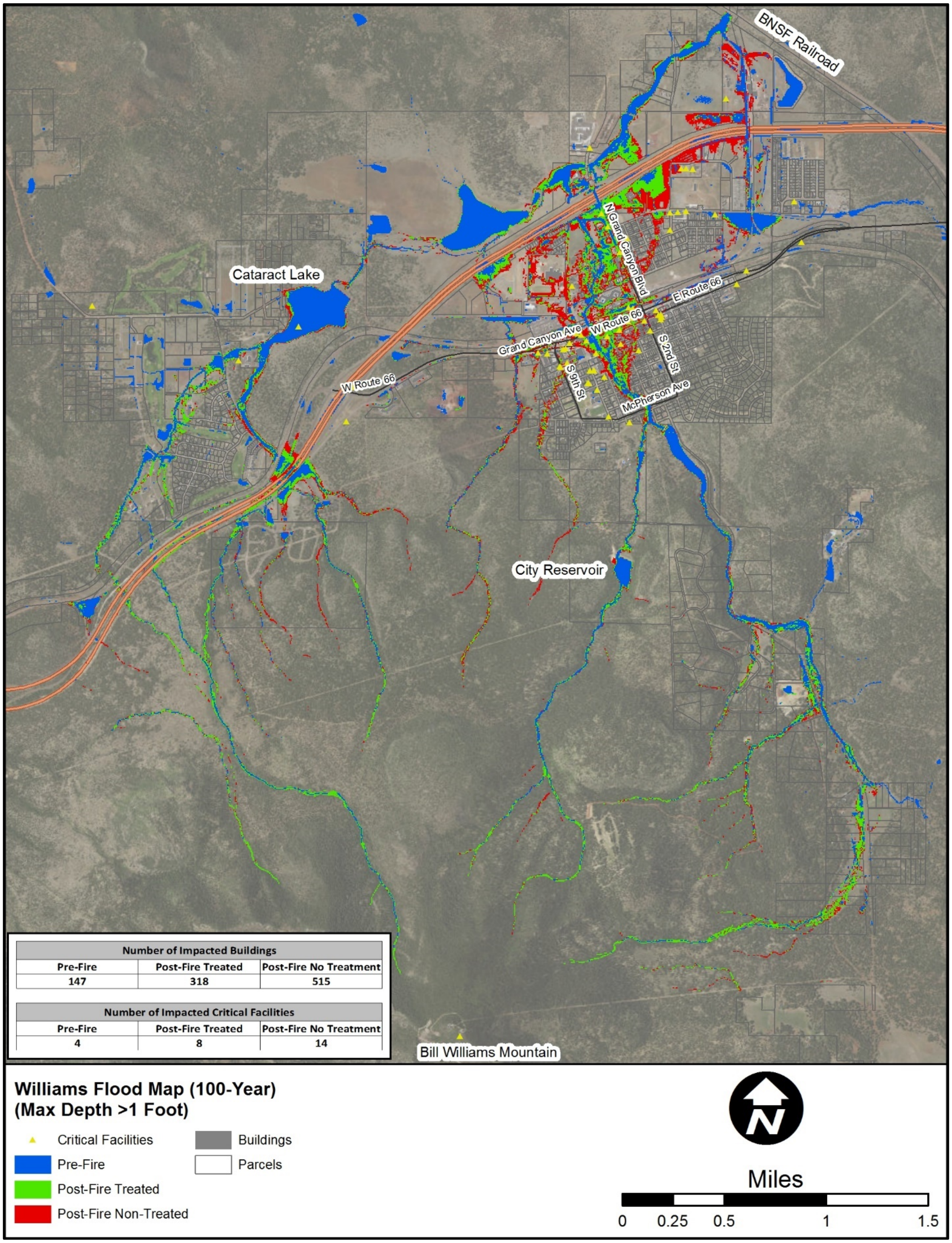
Figure 24 - Williams 2-Year Flood Limit Map


BNSF Railroad
Cataract Lake
N Grand Canyon Blvd
E Route 66
W Route 66
Grand Canyon Ave
S 2nd St
S 9th St
McPherson Ave
City Reservoir
Bill Williams Mountain
Williams Flood Map (10-Year)
(Max Depth >1 Foot)
Critical Facilities
Pre-Fire
Post-Fire Treated
Post-Fire Non-Treated
Buildings
Parcels
N
Miles
0
0.25
0.5
1
1.5

Number of Impacted Buildings		
Pre-Fire	Post-Fire Treated	Post-Fire No Treatment
41	105	268

Number of Impacted Critical Facilities		
Pre-Fire	Post-Fire Treated	Post-Fire No Treatment
1	4	7

Figure 25 - Williams 10-Year Flood Limit Map


BNSF Railroad
Cataract Lake
N Grand Canyon Blvd
E Route 66
W Route 66
Grand Canyon Ave
S 2nd St
S 9th St
McPherson Ave
W Route 66
City Reservoir
Bill Williams Mountain
Williams Flood Map (100-Year)
(Max Depth >1 Foot)
▲ Critical Facilities
🟦 Pre-Fire
🟩 Post-Fire Treated
🟥 Post-Fire Non-Treated
Buildings
Parcels
N
Miles
0
0.25
0.5
1
1.5

Number of Impacted Buildings		
Pre-Fire	Post-Fire Treated	Post-Fire No Treatment
147	318	515

Number of Impacted Critical Facilities		
Pre-Fire	Post-Fire Treated	Post-Fire No Treatment
4	8	14

Figure 26 - Williams 100-Year Flood Limit Map

4.5 WILLIAMS RISK ZONE MAPPING

The findings from the pre- and post-fire flooding and debris flow assessments are summarized in the following non-regulatory risk zone maps. The risk zone maps presented in Figure 27 to Figure 29 indicate the type of hazard (pre-fire flood, post-fire flood, post-fire debris flow, etc.) for the 2-, 10-, and 100-year events. Large format maps are provided in Appendix F.

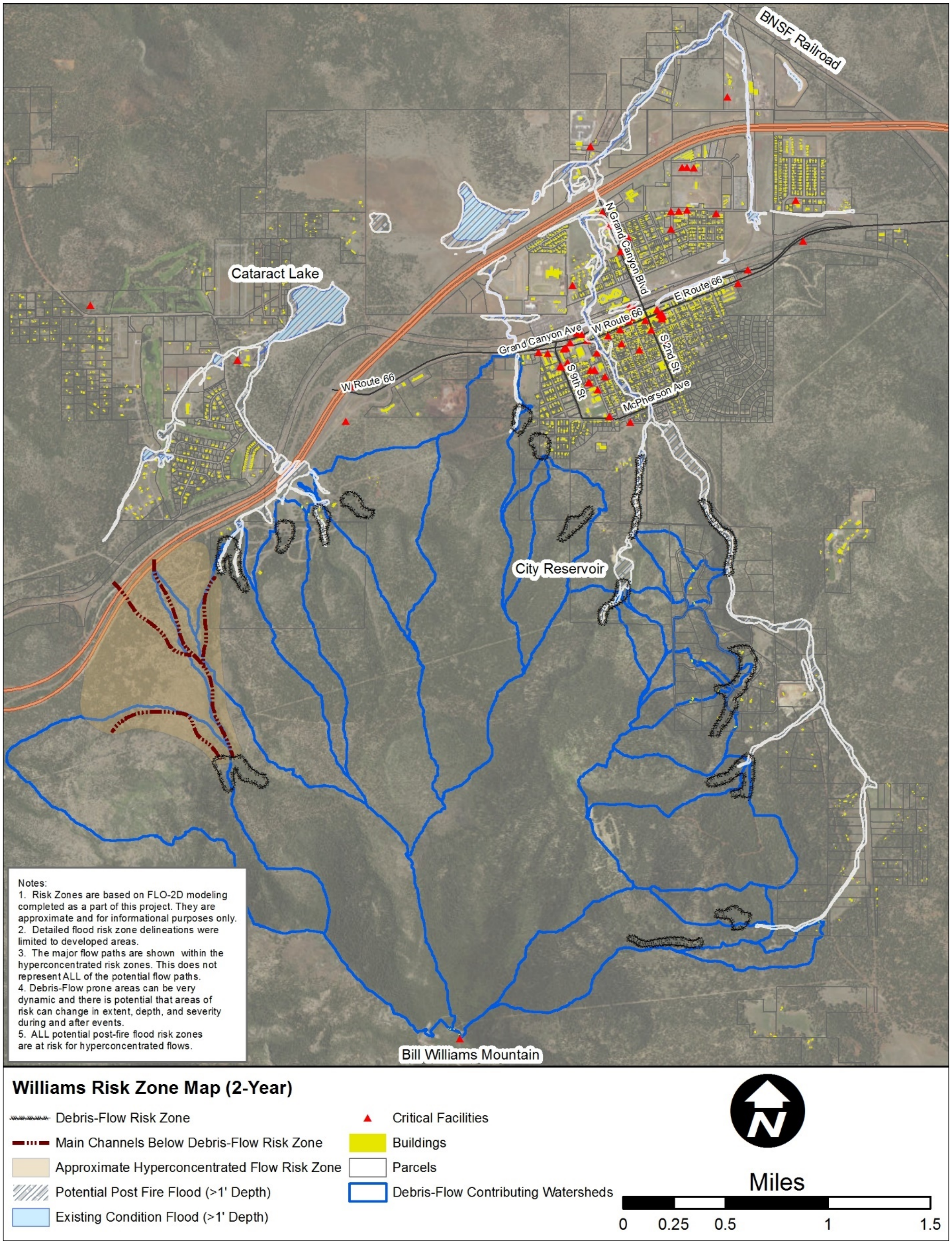
The types of risk zones are summarized below:

Existing Condition Flood – Areas which will potentially be inundated by floodwaters greater than 1 foot in depth if the referenced event occurred in the watershed in its current condition. The shallow flood limits may extend beyond the boundaries presented.

Potential Post-Fire Flood – Areas which will potentially be inundated by floodwaters greater than 1 foot in depth if the referenced event occurred in the watershed in post-fire, untreated conditions (fire burns the watershed in its current condition). The post-fire flood within the Fort Valley study area will most likely consist of hyperconcentrated flood flows (sediment, ash, rocks, debris), similar to the post-Schultz-Fire flooding. Shallow flood limits may extend beyond the boundaries presented.

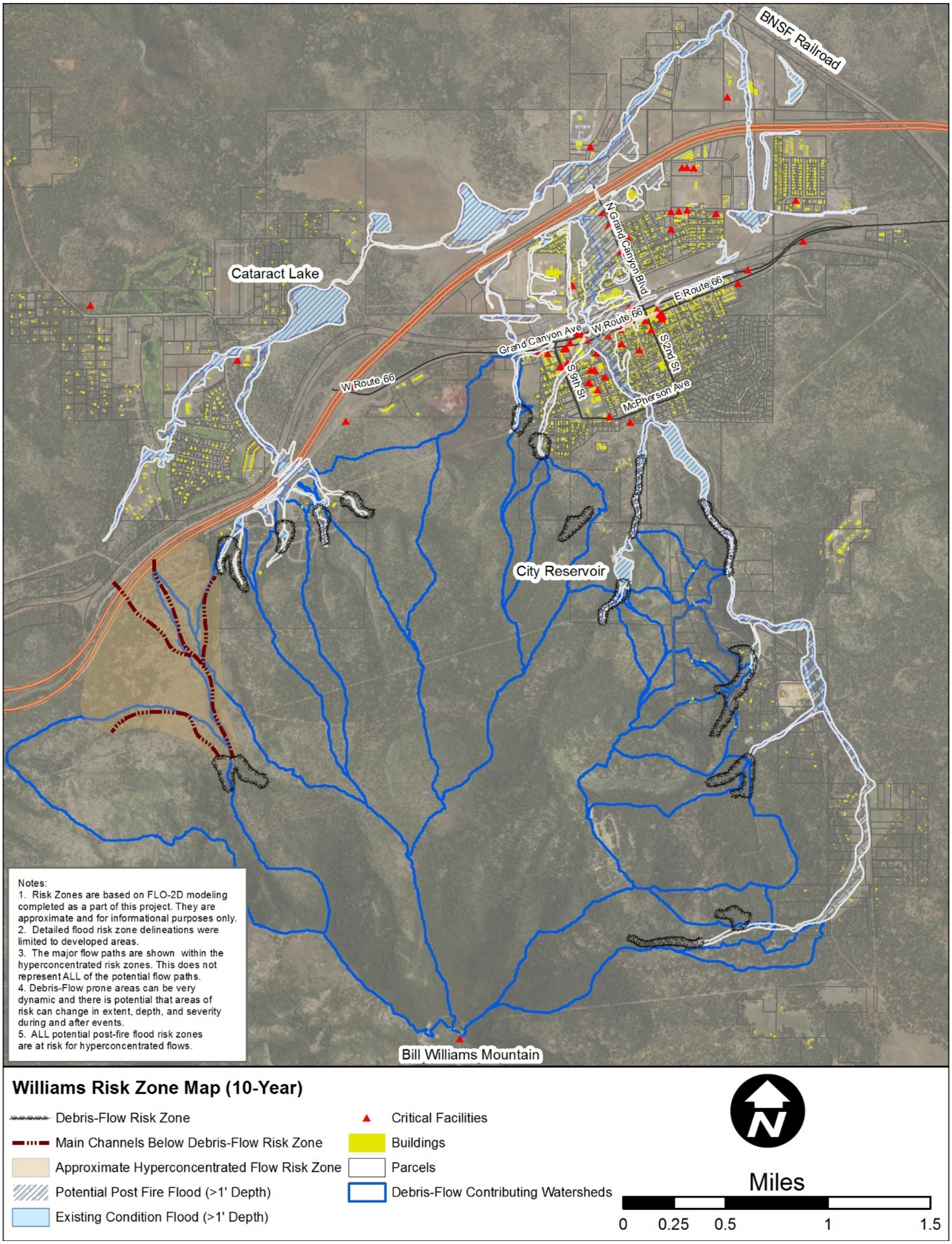
Post-Fire Debris Flow – Areas which may be produce post-fire debris flows. Debris flows erode and scour channels as they travel downslope, releasing sediment for additional transport by hyperconcentrated flows and sediment-laden flood flows. While debris flows may not travel far enough to directly impact houses, infrastructure or other critical facilities, they will indirectly impact these areas of concern by eroding and transporting released sediments via hyperconcentrated and flood flows. Downstream areas will see a significant increase in flooding and sedimentation after wildfires.

Post-Fire Hyperconcentrated Flow – Areas downstream of debris flows which may experience severe erosion, and transport the sediment, water and debris from the base of the potential debris flow to the flood inundation area.


BNSF Railroad
Cataract Lake
N Grand Canyon Blvd
E Route 66
W Route 66
Grand Canyon Ave
S 2nd St
S 9th St
McPherson Ave
W Route 66
City Reservoir
Bill Williams Mountain
Williams Risk Zone Map (2-Year)
Debris-Flow Risk Zone
Main Channels Below Debris-Flow Risk Zone
Approximate Hyperconcentrated Flow Risk Zone
Potential Post Fire Flood (>1' Depth)
Existing Condition Flood (>1' Depth)
Critical Facilities
Buildings
Parcels
Debris-Flow Contributing Watersheds
N
Miles
0
0.25
0.5
1
1.5

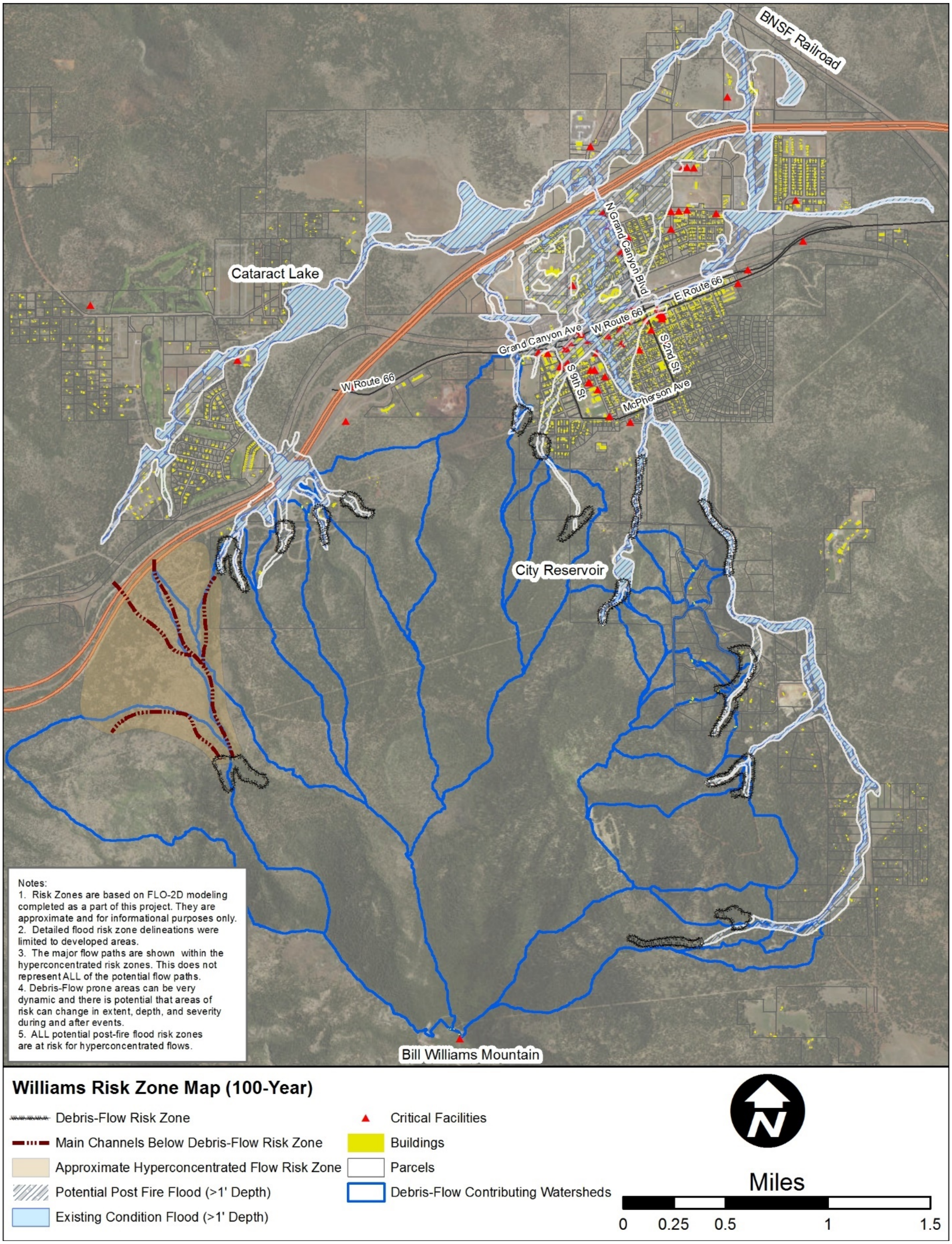
Notes:
1. Risk Zones are based on FLO-2D modeling completed as a part of this project. They are approximate and for informational purposes only.
2. Detailed flood risk zone delineations were limited to developed areas.
3. The major flow paths are shown within the hyperconcentrated risk zones. This does not represent ALL of the potential flow paths.
4. Debris-Flow prone areas can be very dynamic and there is potential that areas of risk can change in extent, depth, and severity during and after events.
5. ALL potential post-fire flood risk zones are at risk for hyperconcentrated flows.

Figure 27 – Williams 2-Year Risk Zone Map


BNSF Railroad
Cataract Lake
N Grand Canyon Blvd
E Route 66
W Route 66
Grand Canyon Ave
S 2nd St
S 9th St
McPherson Ave
W Route 66
City Reservoir
Bill Williams Mountain
Williams Risk Zone Map (10-Year)
Debris-Flow Risk Zone
Main Channels Below Debris-Flow Risk Zone
Approximate Hyperconcentrated Flow Risk Zone
Potential Post Fire Flood (>1' Depth)
Existing Condition Flood (>1' Depth)
Critical Facilities
Buildings
Parcels
Debris-Flow Contributing Watersheds
N
Miles
0
0.25
0.5
1
1.5

Notes:
1. Risk Zones are based on FLO-2D modeling completed as a part of this project. They are approximate and for informational purposes only.
2. Detailed flood risk zone delineations were limited to developed areas.
3. The major flow paths are shown within the hyperconcentrated risk zones. This does not represent ALL of the potential flow paths.
4. Debris-Flow prone areas can be very dynamic and there is potential that areas of risk can change in extent, depth, and severity during and after events.
5. ALL potential post-fire flood risk zones are at risk for hyperconcentrated flows.

Figure 28 – Williams 10-Year Risk Zone Map


BNSF Railroad
Cataract Lake
N Grand Canyon Blvd
E Route 66
W Route 66
Grand Canyon Ave
S 2nd St
S 9th St
McPherson Ave
W Route 66
City Reservoir
Bill Williams Mountain
Williams Risk Zone Map (100-Year)
Debris-Flow Risk Zone
Main Channels Below Debris-Flow Risk Zone
Approximate Hyperconcentrated Flow Risk Zone
Potential Post Fire Flood (>1' Depth)
Existing Condition Flood (>1' Depth)
Critical Facilities
Buildings
Parcels
Debris-Flow Contributing Watersheds
N
Miles
0
0.25
0.5
1
1.5

Notes:
1. Risk Zones are based on FLO-2D modeling completed as a part of this project. They are approximate and for informational purposes only.
2. Detailed flood risk zone delineations were limited to developed areas.
3. The major flow paths are shown within the hyperconcentrated risk zones. This does not represent ALL of the potential flow paths.
4. Debris-Flow prone areas can be very dynamic and there is potential that areas of risk can change in extent, depth, and severity during and after events.
5. ALL potential post-fire flood risk zones are at risk for hyperconcentrated flows.

Figure 29 – Williams 100-Year Risk Zone Map

5 MITIGATION STRATEGIES AND IMPLEMENTATION

In their current condition, the flooding and debris flow risks in the Williams and Fort Valley watersheds are relatively well understood. Both watersheds show signs of past debris flows and the flood risks are noted on the current Flood Insurance Rate Maps and the pre-fire FLO-2D modeling completed as a part of this project. The challenge within these watersheds, which this study attempts to address, is identifying and quantifying the *potential* for increased flood and debris flow risk due to a wildfire. The increased risk is highly dependent upon many variables, and as such, mitigation strategies which reduce the risk potential can and must take many forms.

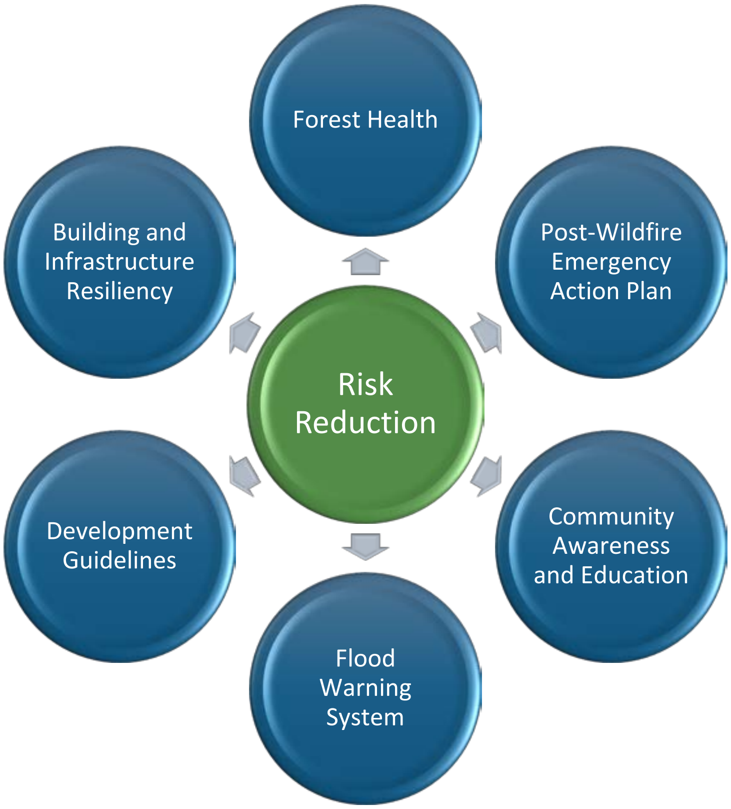

Forest Health
Building and Infrastructure Resiliency
Post-Wildfire Emergency Action Plan
Risk Reduction
Development Guidelines
Community Awareness and Education
Flood Warning System

Figure 30 - Areas of Mitigation Interest

The focus of mitigation strategies identified within this study are *pre-wildfire* activities which will help to inform post-wildfire activities in the event of a wildfire. Mitigation activities identified within this study are referred to as Areas of Mitigation Interest (AoMI). Those AoMI described herein (Figure 30) have been identified and compiled by Coconino County, JE Fuller, Arizona Geological Survey, and other project stakeholders. Coconino County has a significant amount of forested lands which have the potential to burn and create risk for post-wildfire floods and debris flows. It is important to note that while this study is focused on the Fort Valley and Williams Pilot Areas, the AoMI listed within can be modified and applied to any watershed where there is potential for damages to a community due to post-fire flooding or debris flows.

5.1 AREAS OF MITIGATION INTEREST

Six (6) AoMI have been identified and are described in the following sections.

5.1.1 Forest Health

Perhaps the most important and effective mitigation strategy within any watershed, and specifically the Williams and Fort Valley watersheds, is promotion of forest health. Wildfire has been suppressed for many years and in many locations. Current forest conditions include significant overgrowth and dead fuel loads on the ground (Figure 31). Due to these conditions, the path to achieving forest health is not easy and must include many stakeholders and public participation. There is a growing awareness of the need for forest health with the current trends of landscape-changing wildfires such as the Rodeo-Chedeski (2002), Wallow (2011), and Schultz (2010) Fires.

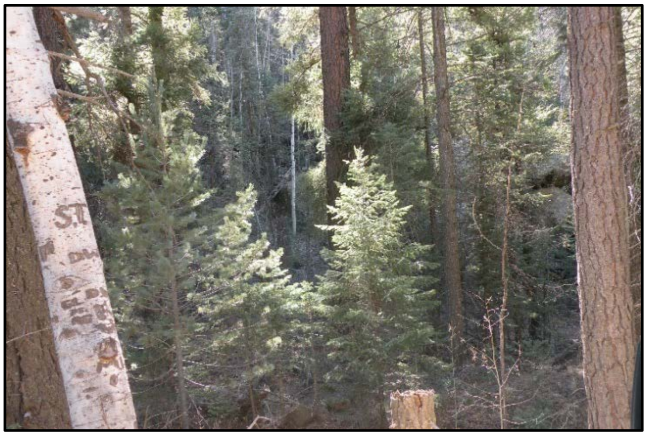


Figure 31 - Current Forest Conditions (Courtesy of Flagstaffwatershedprotection.org)

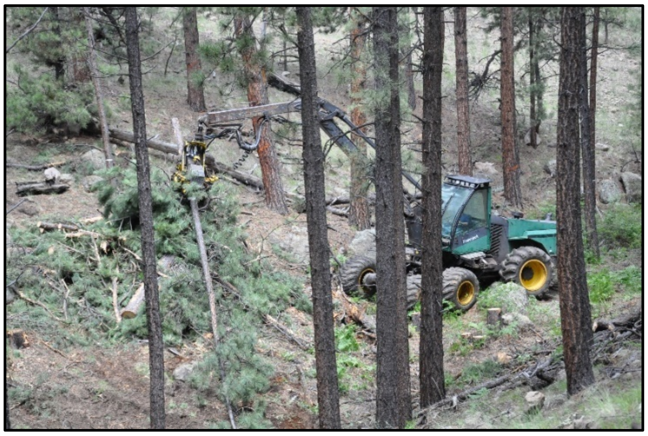


Figure 32 - Mechanical Thinning (Courtesy of Flagstaffwatershedprotection.org)

Forest treatment is one of the first steps towards promotion of forest health. Treatment may include mechanical thinning, control burns, or other methods to reduce the existing fuel load within the forest. Landscape-wide thinning efforts typically require machine-based methods similar to those currently being utilized for the Flagstaff Watershed Protection Project (Figures 31 and 32).

Current initiatives within Northern Arizona that may affect the pilot areas include:

- **Four Forest Restoration Initiative (4FRI)**. "The 4 Forest Restoration Initiative has been created to launch an accelerated restoration program that will restore watershed health and function, improve wildlife habitat, conserve biodiversity, protect old-growth, reduce the risk of uncharacteristic wildland fire and promote the reintroduction of natural fire, and restore natural forest structure and function so that forests are more resilient to climate change."[13] The overall project extents include the San Francisco Peaks (Figure 33), however, the majority of the Upper Rio de Flag Watershed that contributes to the flooding in Fort Valley is not included in the current proposed treatment plan (Figure 34). The wilderness area is excluded and a portion of the watershed is noted as being included in the Wing Mountain Project Area. Specific details about the treatment included in the Wing Mountain Project and the implementation schedule were not researched with this project.

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[13] 4fri.org

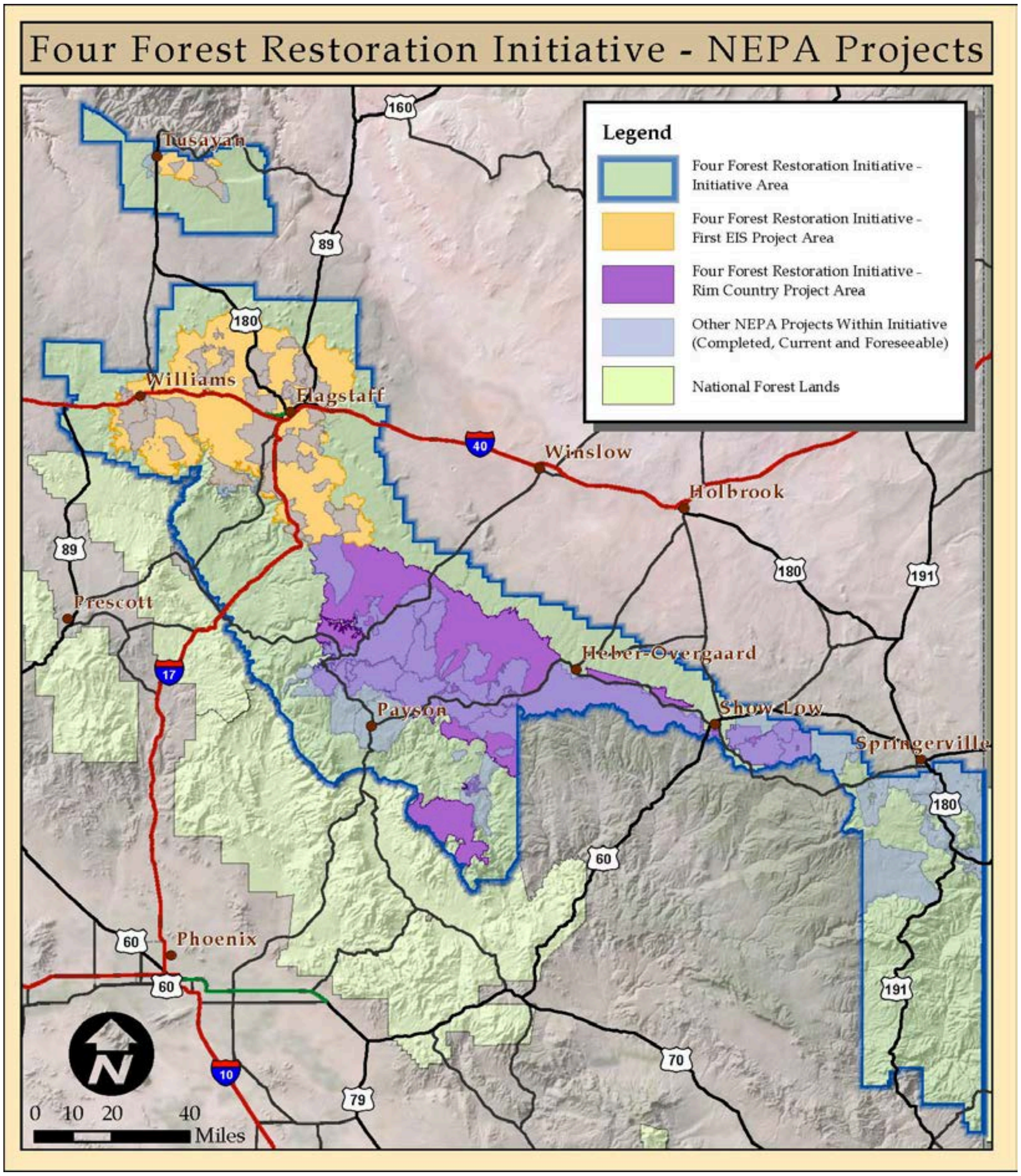
Four Forest Restoration Initiative - NEPA Projects
Legend
Four Forest Restoration Initiative - Initiative Area
Four Forest Restoration Initiative - First EIS Project Area
Four Forest Restoration Initiative - Rim Country Project Area
Other NEPA Projects Within Initiative (Completed, Current and Foreseeable)
National Forest Lands
Tusayan
Williams
Flagstaff
Winslow
Holbrook
Prescott
Heber-Overgaard
Payson
Show Low
Springerville
Phoenix
160
89
180
40
89
180
191
17
180
60
60
60
10
79
70
191
0 10 20 40
Miles

Figure 33 - 4FRI Map (Courtesy of 4fri.org)

- **Flagstaff Watershed Protection Project (FWPP)**. "A partnership effort between the State, City and Coconino National Forest to help reduce the risk of devastating wildfire and post-fire flooding in the Rio de Flag and Lake Mary watersheds." (flagstaffwatershedprotection.org). This includes the Dry Lake Hills area and is outside of the upper Rio De Flag Watershed.
- **Bill Williams Mountain Restoration Project(BWMRP)**. "The purpose of the project is to improve the health and sustainability of forested conditions on and surrounding Bill Williams Mountain by reducing hazardous fuels and moving vegetative conditions in the project area toward desired conditions." The final record of decision, approving the project, was issued on 12/11/15 although the implementation schedule is not yet set. The BWRP has a direct impact on the watershed that impacts the City of Williams and should be viewed as one of the most beneficial AoMI.

5.1.1.1 Fort Valley Forest Health

There are many forest health initiatives that are ongoing in the Fort Valley Watershed, including 4FRI and the Wing Mountain Project. It is recommended that Coconino County discuss the scope and implementation time frame of both projects with the USFS. Also of note within the Fort Valley Watershed, is the Kachina Peaks Wilderness Area. The wilderness area includes the majority of the steep portions of the Peaks where debris flows will tend to form. Although there are restrictions on forest health activities that can happen within the wilderness area, it is recommended the Coconino County begins to coordinate with the Coconino National Forest to determine if there are treatment possibilities (i.e. prescribed burning as opposed to mechanical thinning).

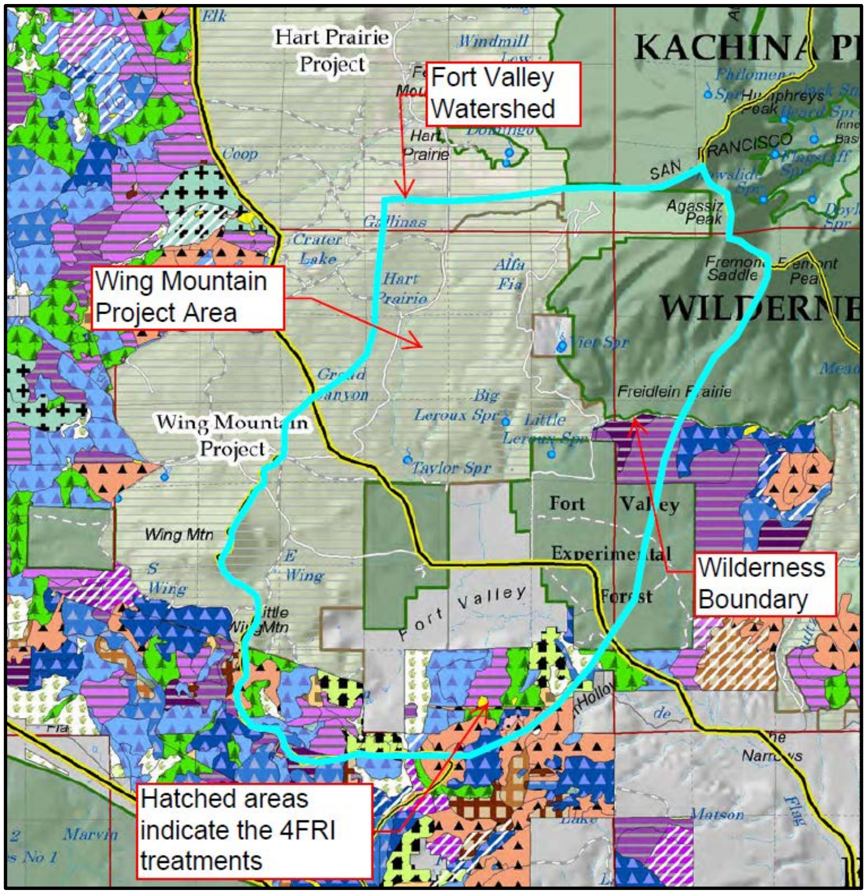
Hart Prairie Project
Fort Valley Watershed
KACHINA
WILDERNE
Wing Mountain Project Area
Wing Mountain Project
Fort Valley Experimental Forest
Wilderness Boundary
Hatched areas indicate the 4FRI treatments
Humphreys Peak
SAN FRANCISCO
Agassiz Peak
Fremont Saddle
Freidlein Prairie
Crater Lake
Hart Prairie
Big Leroux Spr
Little Leroux Spr
Taylor Spr
Wing Mtn
Fort Valley

Figure 34 - Current Initiatives in the Fort Valley Area (Courtesy of 4FRI.org)

5.1.1.2 Williams Forest Health

The USFS has conducted and approved an Environmental Impact Statement (EIS) for the BWMRP. The main challenge is that treating the very steep upper slopes of the mountain is very difficult and will require cable or helicopter logging. Financing the thinning and finding a company to complete the task is a major challenge, and creation of funding partnerships between public and private project stakeholders is key to thinning moving forward. When the project moves forward, priority should be given to the highest priority watersheds that pose the greatest risk to the community. The upper Cataract Creek watershed which feeds into City Dam is one of those watersheds.

5.1.2 Development Guidelines

Reducing future flood and debris flow risk in the Fort Valley and Williams Areas can be in part mitigated by adopting new development guidelines and safe building practices that will make public and private infrastructure and homes more resilient to adverse impacts from future fires and floods. A question that communities should answer is: “How are we decreasing the future damage potential by NOT repeating past practices found to be vulnerable during past floods and fires?”

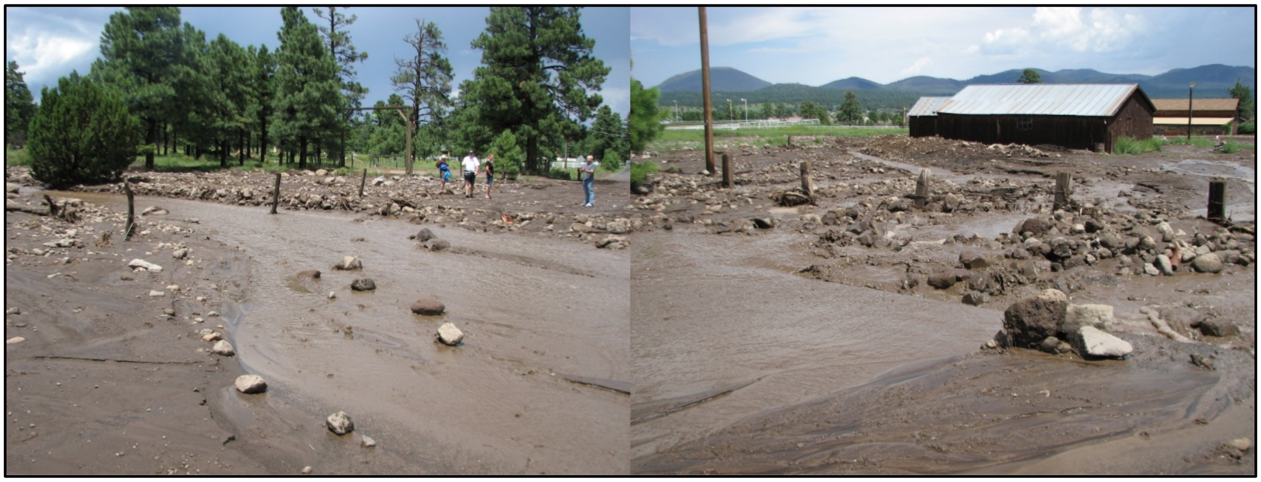

Figure 35 - Timberline Flooding

If communities intend to increase resiliency, guidelines should be specific to the potential flood risk in each pilot area and should be applied to both public and private development and infrastructure. In particular, the following observations are made in each pilot area.

5.1.2.1 Fort Valley Guidelines

Fort Valley is a rural area within the County that experiences development on a lot by lot basis. In general, the flow depths could increase up to 3 feet in the developed area of Fort Valley in post-wildfire conditions. Over 400 acres within Fort Valley are at risk for increased flood water depth during a post-fire 100-year storm, as shown in Figure 36. Current regulations are to set the finished floor at least one foot above the pre-fire 100-year water surface elevation. To prevent post-fire flooding of future development, the County may want to consider revising the minimum finished floor requirements in fire-impacted watersheds, and expand the area of enforcement beyond the existing 100-year floodplain to the 100-year post-fire floodplain footprint.

Additional development guidelines could include:

- Implementing new Finished Floor Elevation requirements based on post-fire flooding.
- Identification of flow corridors to keep open for flood conveyance.
- Fencing guidelines within flow corridors (no solid fencing) to prevent flow diversions and ponding.
- Defining road alignments perpendicular to flow to prevent capturing and redirecting flood flows.
- Aligning homes parallel to flow to minimize flood impacts.
- Identification of open space on each lot to provided conveyance and prevent diversions.
- Promotion of FireWise development practices – cut trees around home, clear brush, etc.

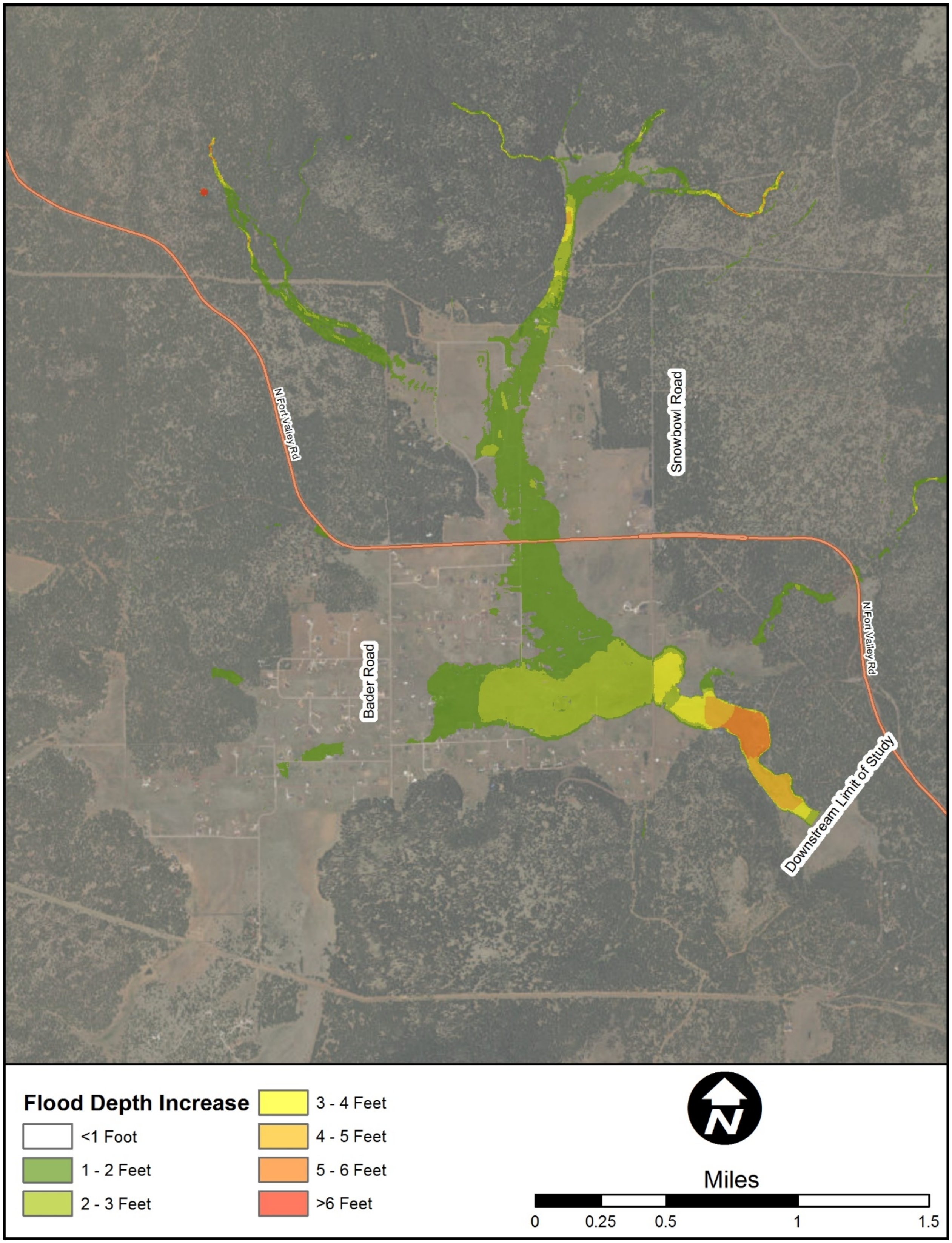
N Fort Valley Rd
Snowbowl Road
Bader Road
N Fort Valley Rd
Downstream Limit of Study
Flood Depth Increase
<1 Foot
1 - 2 Feet
2 - 3 Feet
3 - 4 Feet
4 - 5 Feet
5 - 6 Feet
>6 Feet
N
Miles
0
0.25
0.5
1
1.5

Figure 36 - Fort Valley 100-Year Flood Depth Increase Due to Fire

5.1.2.2 Williams Guidelines

Williams differs from Fort Valley in that is has denser development and is substantially built-out, resulting in higher post-fire flood risk. Within a large percentage of the downtown area, there is potential for the 100-year flood depths to increase by 1 to 2 feet due to wildfire (Figure 37). Certain locations south of I-40 may see a more severe increase in flood depths due to the limited capacity of the structures under the highway. The City may wish to consider the following:

- Implementing new Finished Floor Elevation requirements based on post-fire flooding for new structures.
- Establishing guidelines for remodels and substantial improvements. This could include floodproofing, lot grading, minimum finished floor elevation requirements.
- Future CIP projects should include upsizing structures to handle post-fire conditions.

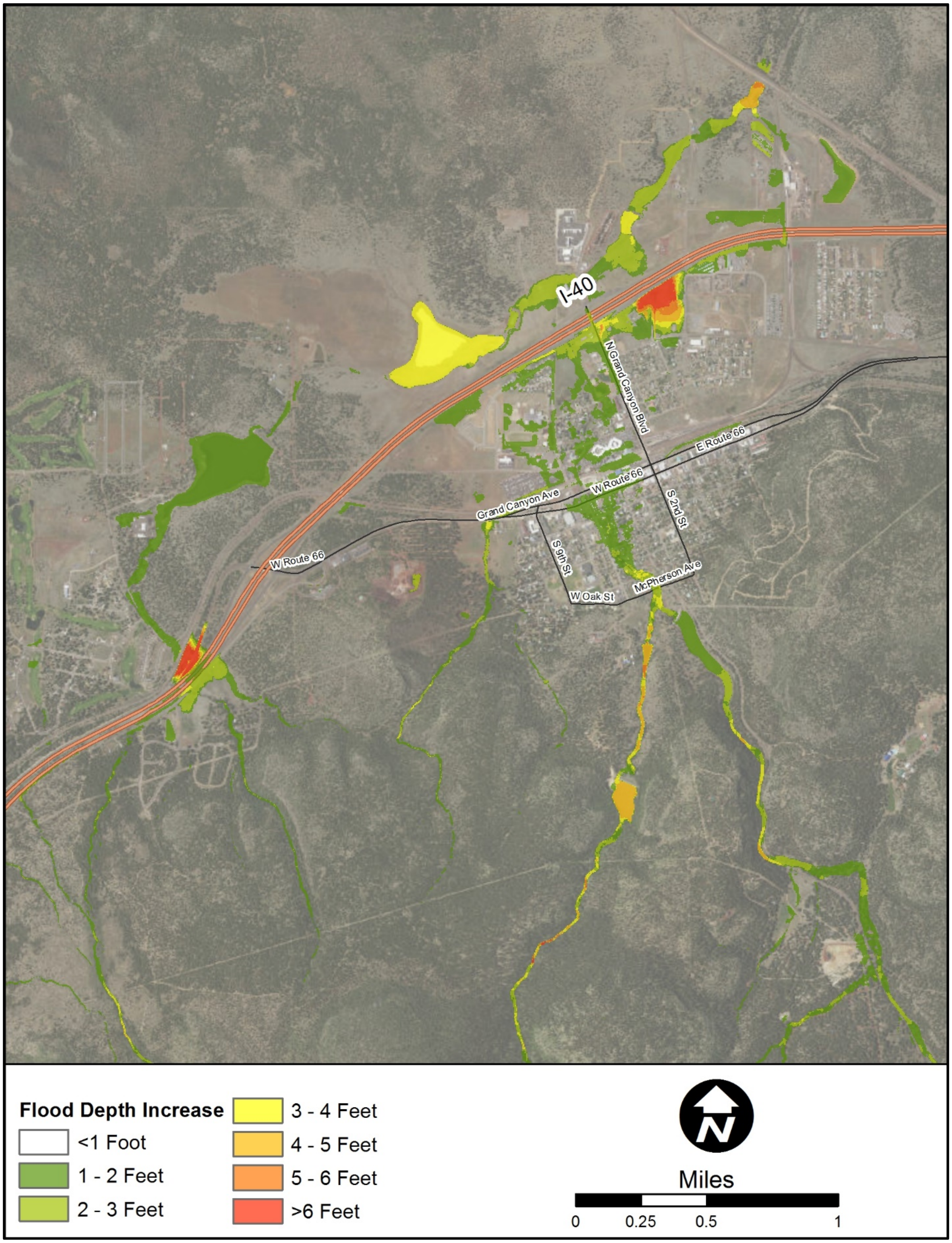
I-40
N Grand Canyon Blvd
E Route 66
W Route 66
Grand Canyon Ave
S 2nd St
S 9th St
W Route 66
W Oak St
McPherson Ave
Flood Depth Increase
<1 Foot
1 - 2 Feet
2 - 3 Feet
3 - 4 Feet
4 - 5 Feet
5 - 6 Feet
>6 Feet
N
Miles
0
0.25
0.5
1

Figure 37 - Williams Flood Depth Increase Due to Fire

5.1.3 Community Awareness and Education

The risk posed by post-wildfire flooding and debris flows can be challenging to convey to the public because they are dependent on a wildfire taking place. Educating the public about the risk, and the many forms that it can take, is critical to taking steps to reduce the risk. The Schultz Fire and resulting flooding came as a surprise to many people since many of the drainages originating on the mountain rarely have water in them and may not look like a flood channel to untrained observers. These seemingly minor drainage paths became incised channels due to the debris flows and increased flooding after the fires. They transported sediment, debris, and flood water into the developed portions of Timberline, Doney Park, and areas downstream. Had the public, developers and regulatory agencies been aware of the potential for flooding due to a wildfire, planning and response to the flooding may have taken a different form. When the Schultz Fire and ensuing flooding began, Coconino County rose to the challenge and was very proactive in engaging the public and partnering agencies to protect life and property and develop mitigation solutions. The challenge now is to plan ahead in vulnerable areas to stay one step ahead of the post-fire risk by making the community aware of the risk and how to plan for it.

The National Flood Insurance Program(NFIP) provides guidelines for developing a Program for Public Information(PPI) which is credible towards the County's FEMA CRS Rating. The PPI must include at least five members and can include individuals from public agencies, community groups, local insurance agents, and/or local bank representatives. The purpose is to provide input from many different sources and convey information to the public in ways that everyone can understand.

Steps the County can take now may include the following:

- Education of the safest exit routes and safety zones.
- Development of PPI's for both Fort Valley and Williams to begin the process of educating the public to the potential risk.
- Develop an educational pamphlet to hand out with building permit.
- Beginning public service announcements in the most vulnerable areas.
- Encouraging homeowners in vulnerable areas to get flood insurance before or immediately when a fire starts.
- Engaging and partnering with Arizona Department of Forestry and Fire Management through their Prevention Programs[14] is another path for educating the public in the wildland-urban interface.

5.1.4 Flood Warning System

A flood warning system within a burnt watershed can be a tool to monitor the potential for debris flow or flood risk. As experienced after the Schultz Fire, there was very little time to install rainfall gages between the end of the fire and the first rainfall events. If the equipment is not on hand at the time of the fire, there is potential that installations will not happen prior to rainfall events. Strategically placed rainfall gages that are installed within vulnerable watersheds before a fire can provide beneficial information to the County or City. Because there is a risk that gages can be damaged during the fire, it is recommended that the County develop a plan for immediate post-fire rainfall gage installation. This plan could include identifying potential locations, maintaining a surplus of equipment, and understanding easements or permitting that may be required. A plan could be developed specifically for the Williams and Fort Valley Watersheds and modified as necessary if a fire occurs in a different location.

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[14] https://dffm.az.gov/fire/prevention

Currently there are two rainfall gages on Bill Williams Mountain; one at City Dam which is owned by the Arizona Department of Water Resources (ADWR), and one at the summit owned by Yavapai County. Three additional locations at the Williams Ski Area, USFS Work Center, and Perkinsville Road are recommended and noted on Figure 38 and may be beneficial to flood warning in the event of a fire.

The Fort Valley Watershed currently does not have any rainfall gages. There are two locations that are both easily accessible and may be beneficial to post-fire flood warning. The first location is at Arizona Snowbowl and the second is at the lower reclaimed water pump station on Snowbowl Road as noted on Figure 39. The National Weather Service should be involved in the discussion of the final placements.

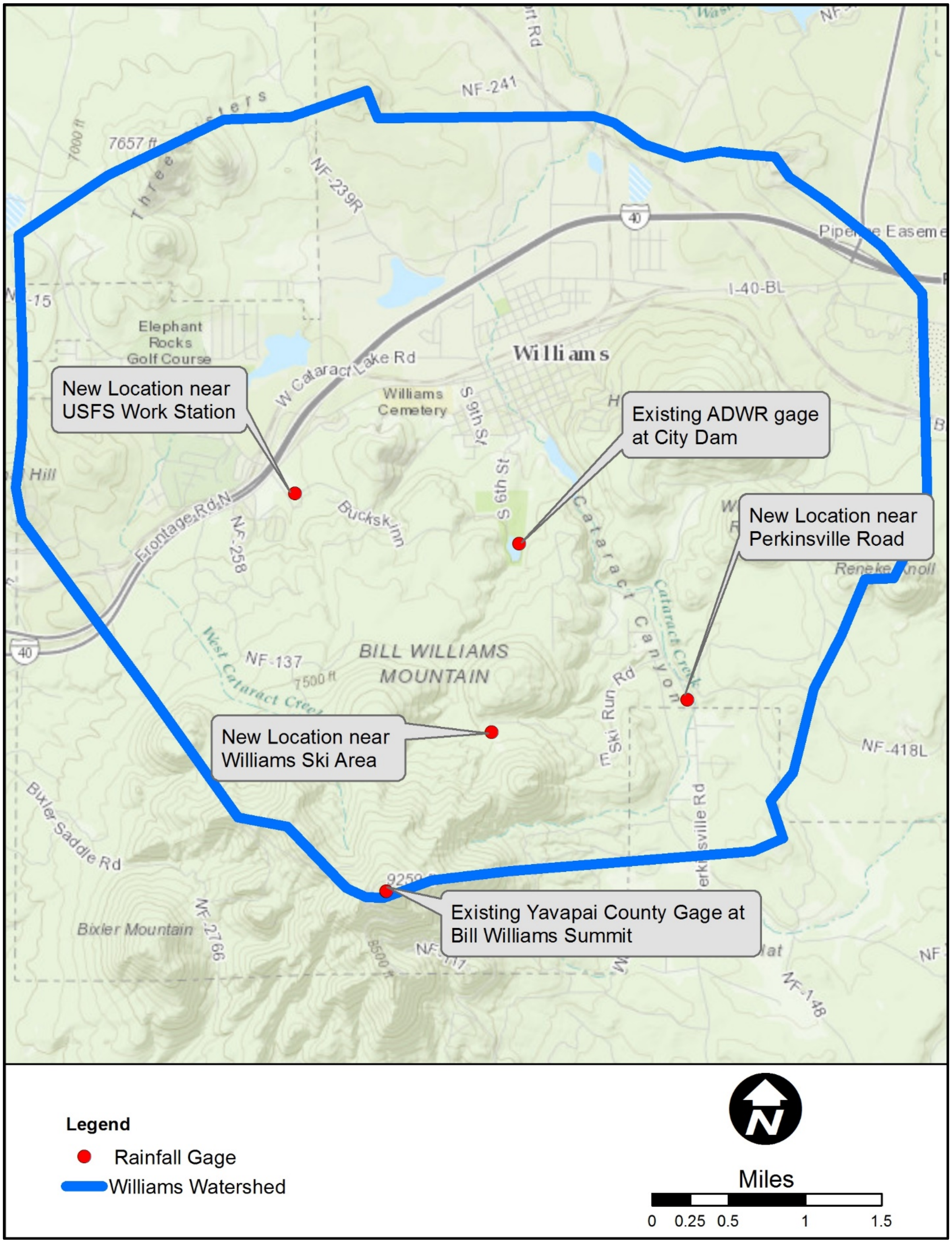
New Location near USFS Work Station
Existing ADWR gage at City Dam
New Location near Perkinsville Road
New Location near Williams Ski Area
Existing Yavapai County Gage at Bill Williams Summit
Williams
Elephant Rocks Golf Course
Williams Cemetery
BILL WILLIAMS MOUNTAIN
Bixler Mountain
Bixler Saddle Rd
W Cataract Lake Rd
Frontage Rd N
S 9th St
S 6th St
Cataract Canyon
Cataract Creek
West Cataract Creek
Ski Run Rd
Perkinsville Rd
Reneke Knoll
Pipeline Easement
I-40-BL
40
NF-241
NF-239R
NF-258
NF-137
NF-418L
NF-2766
NF-148
7657 ft
7500 ft
9259
8500 ft
Legend
● Rainfall Gage
Williams Watershed
N
Miles
0
0.25
0.5
1
1.5

Figure 38 - Williams Rainfall Gage Locations

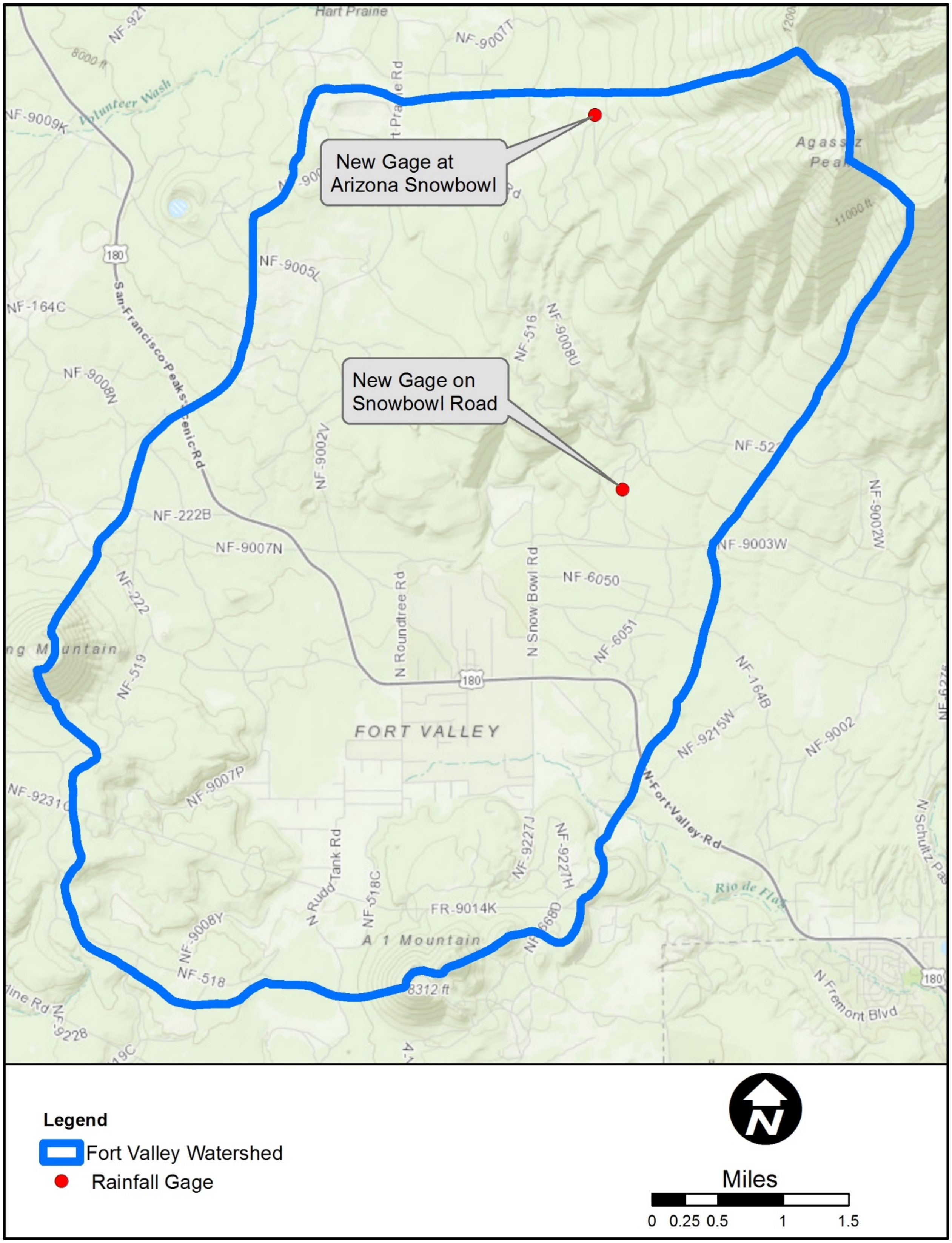
New Gage at Arizona Snowbowl
New Gage on Snowbowl Road
Hart Prairie
NF-9007T
Agassiz Peak
11000 ft
8000 ft
Volunteer Wash
NF-9009K
180
NF-164C
San-Francisco-Peaks-Scenic-Rd
NF-9005L
NF-9008N
NF-516
NF-9008U
NF-9002V
NF-222B
NF-9007N
NF-222
NF-519
NF-6050
NF-6051
NF-9003W
NF-9002W
N Roundtree Rd
N Snow Bowl Rd
FORT VALLEY
NF-164B
NF-9215W
NF-9002
N-Fort-Valley-Rd
Rio de Flag
N Schultz Pass
NF-9007P
NF-9231
N Rudd Tank Rd
NF-518C
NF-9227J
NF-9227H
FR-9014K
A 1 Mountain
NF-9008Y
NF-518
8312 ft
N Fremont Blvd
NF-9228
Legend
Fort Valley Watershed
● Rainfall Gage
N
Miles
0
0.25
0.5
1
1.5

Figure 39 - Fort Valley Rainfall Gage Locations

5.1.5 Post-Wildfire Emergency Action Plan

The US Forest Services utilizes Burned Area Emergency Response Teams (BAER) to assess post-fire conditions and determine emergency stabilization or treatments to protect life and property. These teams often rely on information provided by local communities to develop and implement a plan. They are however restricted to assessments and treatments on forest land only.

Coconino County or the City of Williams could proactively prepare a Post-Wildfire Emergency Action Plan (EAP) that can be provided to a BAER team to better coordinate the emergency work directly after a fire and implement treatments on non-forest land. The EAP could include:

- Potential flood and debris flow risk maps.
- Evacuation plan and major evacuation route identification.
- Identification of major utilities, critical facilities, and infrastructure in the area that should be protected.
- Community Outreach Plan to help homeowners understand the risk and how to plan for it.
- Creation of a plan to update hydrologic models after a fire begins to understand the risk potential.
- Coordination with the National Weather Service to identify critical rainfall intensities and durations that trigger specific warnings for flood and for debris flow. The warnings could include watches, warnings, evacuations, etc.)

The plan can also list the critical steps that the County needs to take once a fire begins. Figure 40 presents a flow chart for possible action once a fire has begun in a critical watershed.

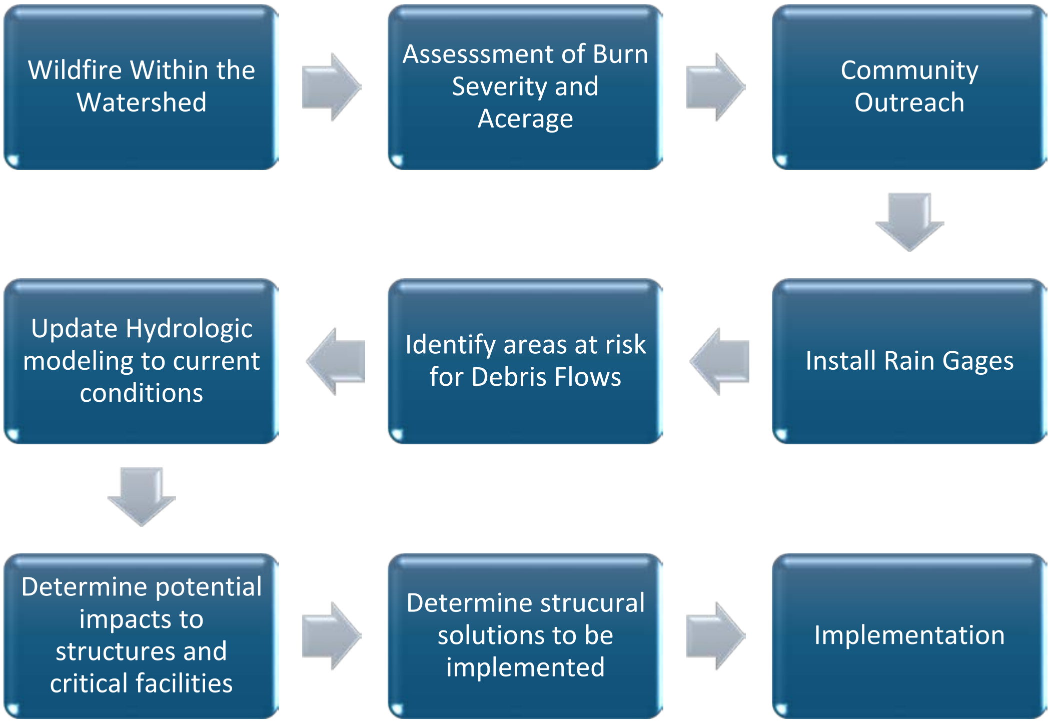
Wildfire Within the Watershed
Assesssment of Burn Severity and Acerage
Community Outreach
Install Rain Gages
Identify areas at risk for Debris Flows
Update Hydrologic modeling to current conditions
Determine potential impacts to structures and critical facilities
Determine strucural solutions to be implemented
Implementation

Figure 40 - Post-Wildfire Emergency Action Plan

Integrated within the emergency action plan is updating the hydrologic conditions of a watershed once a fire begins and assessing the flooding potential in real time as a fire progresses. This can be a critical component of planning for where barriers need to be installed or other improvements constructed prior to potential flood events. Post-Wildfire hydrology has been developed as a part of this project and those parameters could be applied to other watersheds within Coconino County that area affected by wildfire.

5.1.6 Building and Infrastructure Resiliency

In both pilot areas there are a significant number of buildings that may be subject to post-wildfire flooding. One of the most important keys to reducing the risk of post-wildfire flooding is increasing the resiliency of those existing buildings and the infrastructure that serves them. Even if buildings are not impacted, protection of life and property is often contingent upon critical infrastructure providing evacuation routes, emergency access, and utility service to the areas affected by post wildfire flooding. Ways to improve the existing developments resiliency include:

- Post-flood repair guidelines (don’t put it back the way it was, make it better).
- Elevate and floodproof additions and substantial improvements.
- Regrade lots to divert drainage away from structures.
- Relocate driveways and fences out of identified flow corridors.
- Re-landscape lots to provide flood protection to existing structures.

5.1.6.1 Fort Valley Building and Infrastructure Risk

As summarized in the previous sections, many buildings may be inundated in a post-wildfire flood. In addition, there are two main pieces of infrastructure that may be impacted in a debris flow and flood event. Highway 180 crosses through the meadow and has the potential to be damaged in the event of post-fire flooding, which could create access issues for the south and west sides of Fort Valley. There is also a high pressure Transwestern Gas line that crosses the north part of Fort Valley and has a spur that runs south along South Snowbowl Road. Results from the modeling show that post-wildfire flooding would be deeper and faster than existing conditions, creating potential for scour where the flow crosses the line. The pipeline crosses many flowpaths that originate on the upper slopes of the peaks. Experience in the Timberline area after the Schultz Fire showed that small or non-incised channels can become very large with initial post-fire flood events.

Table 10 shows pre-and post-wildfire flow characteristics. Figure 41 shows locations where the pipeline or Highway could be impacted by post fire flooding and debris flows. There are many private roads and infrastructure which may be impacted as well which are not shown on the figure.

Table 10 - Fort Valley Infrastructure Impacts

Infrastructure	**Pre-Fire**		**Post-Fire (untreated watershed)**	
	Depth	Max Velocity	Max Depth	Max Velocity
Highway 180	< 1 foot	< 3 ft/sec	2 feet	7 ft/sec
Transwestern Pipeline (North end of Fort Valley)	< 2 feet	5 ft/sec	4 feet	8 ft/sec
Transwestern Pipeline (S. Snowbowl Road Crossing)	< 2 feet	5 ft/sec	4 feet	6 ft/sec

Another consideration in the Fort Valley area is the presence of shallow wells and septic systems. There is not a public water or sewer system, and each home has an individual well and septic systems. Post-fire flooding has the potential to carry ash, debris, and sediment which will negatively impact both the water quality of shallow wells and the functionality of the existing septic systems.

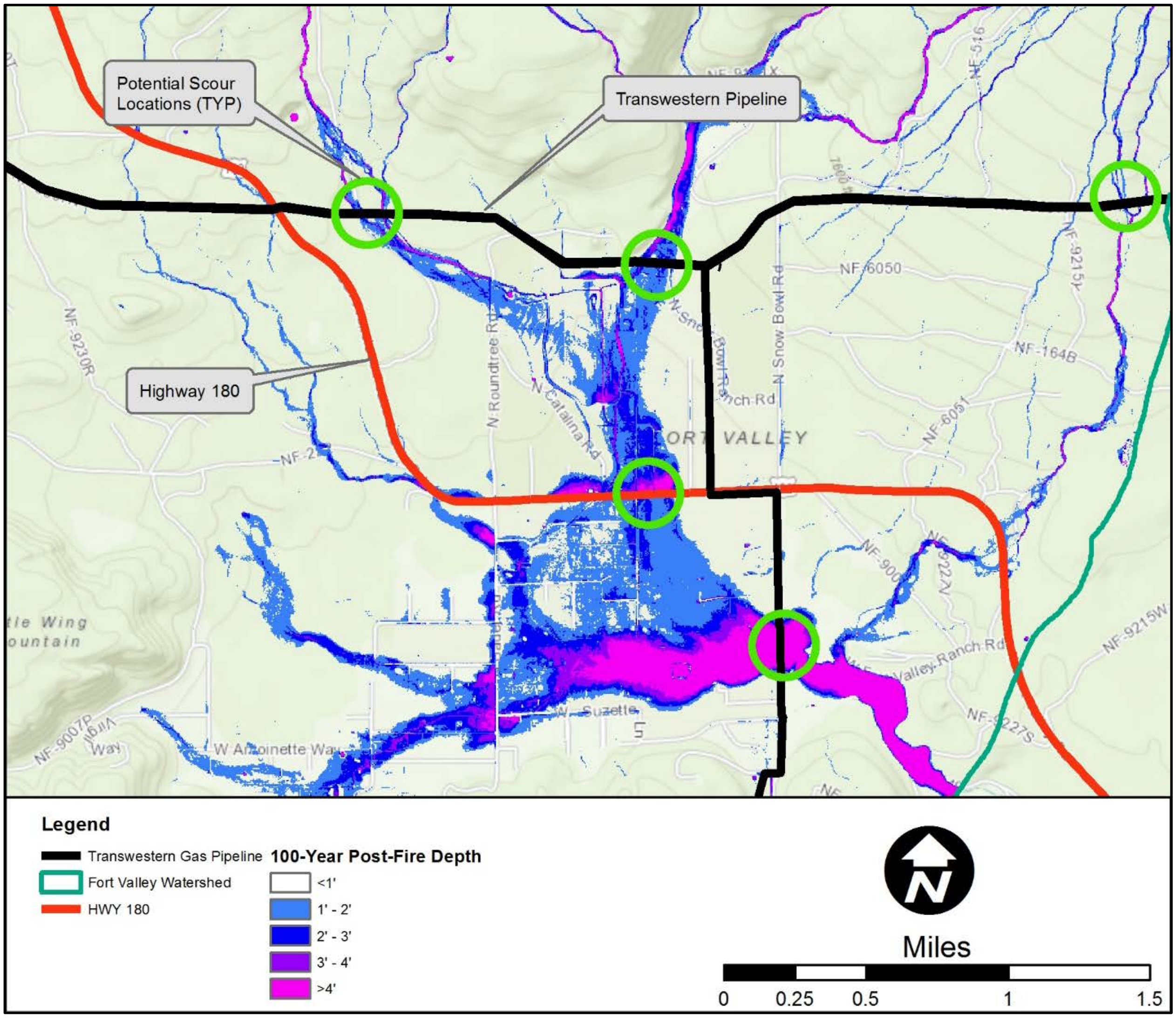
Potential Scour Locations (TYP)
Transwestern Pipeline
Highway 180
NF-9230R
N Roundtree Rd
N Catalina Rd
N Snow Bowl Rd
Snow Bowl Rd
NF 6050
NF-9215Y
NF-164B
NF-6061
FORT VALLEY
NF-9215W
Valley Ranch Rd
NF-9227S
W Suzette
W Antoinette Way
NF-9007P
ttle Wing
ountain
Legend
Transwestern Gas Pipeline
Fort Valley Watershed
HWY 180
100-Year Post-Fire Depth
<1'
1' - 2'
2' - 3'
3' - 4'
>4'
N
Miles
0
0.25
0.5
1
1.5

Figure 41 - Fort Valley Infrastructure

5.1.6.2 Fort Valley Pre-Fire Infrastructure Resiliency Planning

The following recommendations should be considered by public agencies, private entities, and homeowners to plan for post-wildfire impacts and increase the resiliency of existing buildings and infrastructure:

- Transwestern Pipeline. Evaluate the need for additional scour protection at major drainage crossings potentially impacted by post-fire floods.
- State Route 180. Evaluate the need for additional erosion protection at major drainage crossings potentially impacted by post-fire floods.
- Private Homeowners. Develop guidelines for barriers to protect buildings, water wells and septic systems.
- Flow Corridors. Identify critical flow corridors for potential property acquisition or zoning restrictions to preserve flood conveyance.
- Fort Valley Channel. Evaluate potential for developing a flood channel and corridor sized to safely convey post-wildfire flood events through the developed area. The plan may include easement acquisition for the channel so that it could be implemented rapidly in the event of a fire.
- Sediment Basins. Identify possible locations for upstream sedimentation basins and scour prevention similar to methods used after the Schultz Fire, and begin coordination for easements, permitting and access for implementation after wildfires.

It is recommended that ADOT, Transwestern, public utilities, and individual homeowners be informed of the post-fire modeling results to assist them in planning for future development and maintenance of existing structures.

5.1.6.3 Williams Building and Infrastructure Risk

Post-fire flooding impacts to the Williams area have the potential to be severe. Not only would post-fire flows have a direct impact on a significant number of structures, but they may also impact a number of critical facilities, such as dams, public utilities, the public drinking water system, and roads.

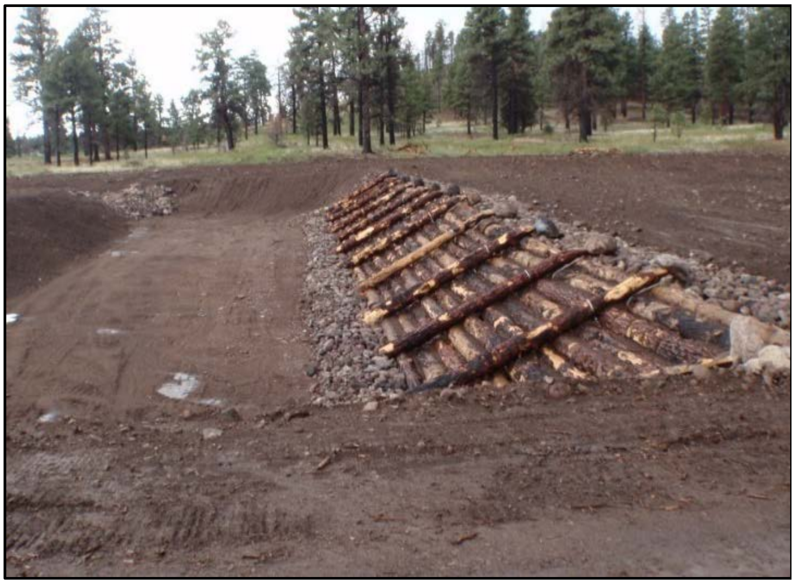

Figure 42 - Schultz Scour Protection and Sedimentation Basin

One of the major sources of drinking water for Williams is the City Reservoir. Post-wildfire runoff into the reservoir is at risk because of the potential for impacts to the water quality due to ash and sediment. The focus of this study is a landscape-sized fire and the ensuing impacts. However, the reservoir is vulnerable to water quality problems even with a small fire in its watershed. Based on the modeling results, there is potential for the reservoir to partially fill with debris and sediment. Although this may not affect the structure of the dam, it will decrease the overall storage volume.

In addition, water velocities within Cataract Creek have the potential to increase by as much as 50%, with greater flow depths. These increases may put public and private utility lines at risk due to increased scour both within the channel as well as in areas immediately adjacent to the channels (e.g., power poles). Similarly, public road crossings may also be at risk due to scour. Possibly a more important consideration than the damage to public roadways, is the potential loss of emergency access routes. Many channels on the west side of Williams also have the potential to be impacted by flood water. Channel scour could lead to the loss of access to several neighborhoods near the Forest Service Work Center and damage existing infrastructure. It is even possible that I-40 would be overtopped in a post-fire flood event and experience scour and damage (Figure 44).

Finally, a significant number of buildings in downtown Williams may be adversely impacted by post-wildfire flood water. Not only would this directly affect the structures and possibly place lives in danger, but it would also have a significant economic impact on tourism, one of Williams' primary sources of revenue.

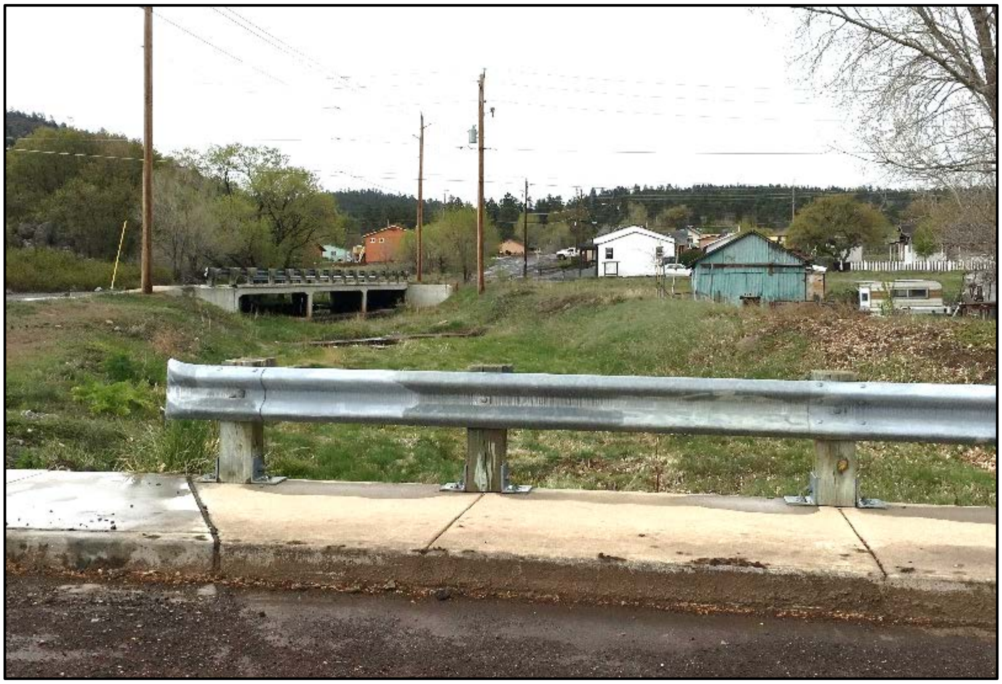

Figure 43 - Cataract Creek where it enters Williams

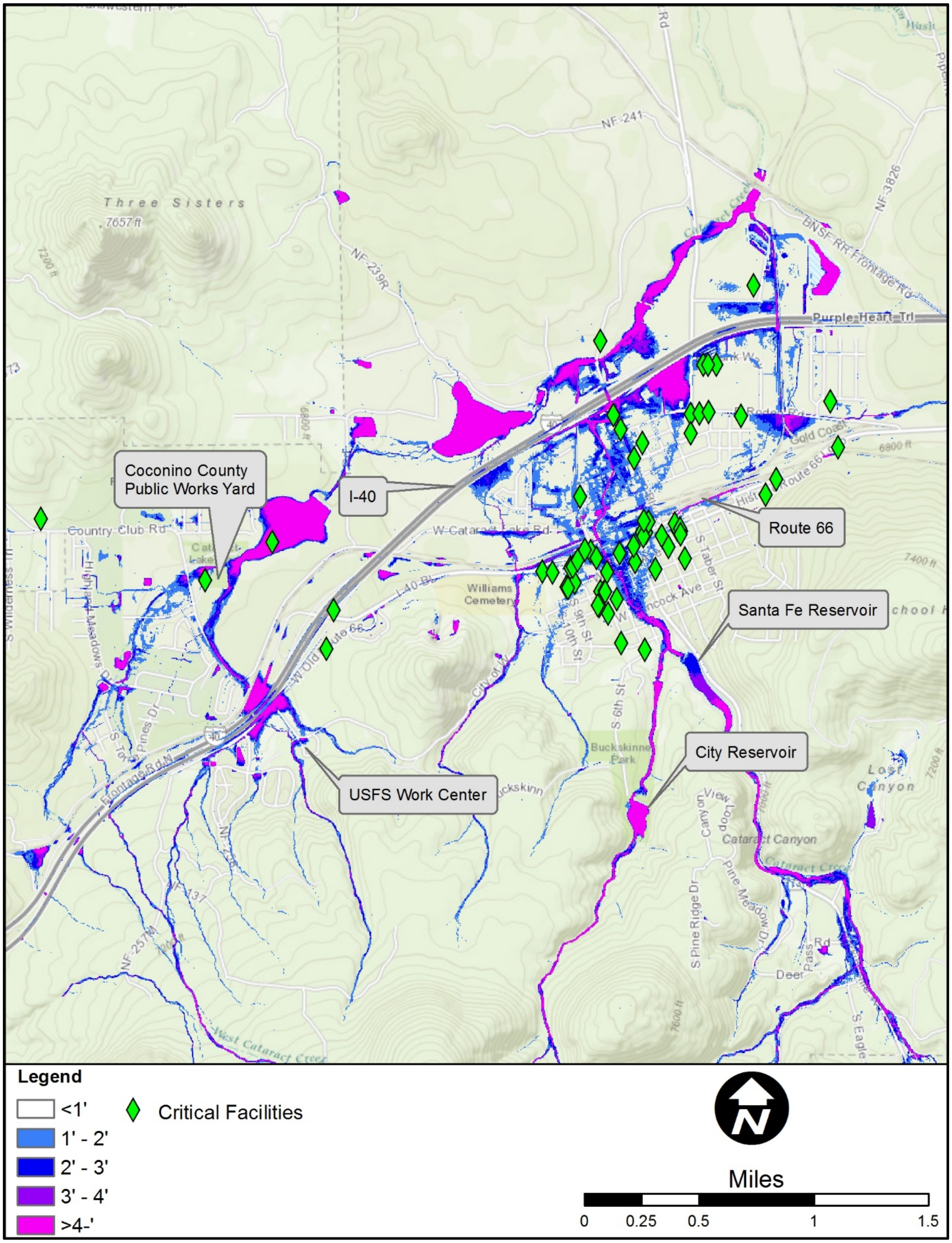
Coconino County Public Works Yard
I-40
Route 66
Santa Fe Reservoir
City Reservoir
USFS Work Center
Three Sisters
7657 ft
NF-241
NF-239R
NF-3826
BNSF RR Frontage Rd
Purple Heart Trl
Country Club Rd
W Cataract Lake Rd
Williams Cemetery
S Taber St
S 9th St
S 10th St
S 6th St
Buckskinner Park
Lost Canyon
Cataract Canyon
Cataract Creek
West Cataract Creek
S Pine Ridge Dr
Pine Meadow Dr
S Eagle
Deer Pass Rd
Frontage Rd N
NF-257M
NF-137
6800 ft
7400 ft
7600 ft
7200 ft
Legend
<1'
1' - 2'
2' - 3'
3' - 4'
>4-'
Critical Facilities
N
Miles
0
0.25
0.5
1
1.5

Figure 44 – Williams Infrastructure Impact

5.1.6.4 Williams Pre-Fire Infrastructure Resiliency Planning

The following recommendations should be considered by public agencies, private entities, and homeowners to plan for post-wildfire impacts and increase the resiliency of existing buildings and infrastructure:

- Protect Critical Infrastructure. Develop flood barrier installation plans specific to each piece of critical infrastructure within Williams, based on post-fire flood depths, velocities and debris flow potential.
- I-40 Erosion Protection. Evaluate the need for additional erosion protection on I-40 where post-fire flood modeling indicates potential overtopping (near the USFS work center).
- Water Supply.
    - Investigate alternative and emergency sources of drinking water.
    - Research potential water filtration units that could protect the existing water treatment plant from ash and sediment laden water if the City Reservoir is impacted. Denver and Fort Collins, CO are good resources for the City of Williams.
- Private Homeowners. Develop guidelines for barriers to protect buildings, water wells and septic systems.
- Utility Crossing Protection. Evaluate the need for scour protection for utility crossings along Cataract Creek within the City of Williams.
- Flood Conveyance Channel(s). Evaluate potential for developing a flood channel and corridor sized to safely convey post-wildfire flood events through the City of Williams. The plan may include easement acquisition for the channel so that it could be implemented rapidly in the event of a fire.
- Sediment Basins. Identify possible locations for upstream sedimentation basins and scour prevention similar to methods used after the Schultz Fire, and begin coordination for easements, permitting and access for implementation after wildfires.

5.2 COMMUNITY OUTREACH AND IMPLEMENTATION

This study is a high-level investigation into the impacts of post-wildfire flooding and debris flows on the communities of Fort Valley and Williams. To date there have not been major fires in either of these watersheds and the challenge faced by local communities is to find reasonable *pre-fire* answers to the following questions.

- What should the County/City's role be in mitigating or minimizing post-wildfire risk?
- What should the private homeowner's/business owner's role be in mitigating or minimizing post-wildfire risk?
- To what extent should structural solutions be implemented in a pre-wildfire condition?
- To what standard should development be regulated in these areas?

With the information presented in this study, potentially impacted stakeholders have the tools to begin the discussion of these questions. Since these are high level policy type decisions, some smaller scale ideas for implementation area as follows:

- Create PPI groups in Fort Valley and Williams.
- Determine a Community Outreach Plan which may include annual public meetings, mailings, etc.
- Do additional detailed modeling to identify the size/scope of improvements that would need to be implemented in certain areas. Perhaps there are smaller scale improvements that will go a long way in increasing the resiliency of the communities.
- Determine easement the extent of easement acquisition necessary to implement some mitigation solutions.

6 CONCLUSION

Coconino County has the unique opportunity to plan for and take steps to mitigate the potential risk posed by post-wildfire flooding and debris flows. Post-fire flood and debris flow hazard areas can be mapped and identified prior to fires as planning tool and as this study shows, significant land areas, structures, critical facilities, and major infrastructure in County are vulnerable to these hazards. A reconnaissance-level countywide FLO-2D analysis completed with this study indicated that approximately **34 percent of buildings and 26 percent of critical facilities** within the County are vulnerable to some type of impact from post-wildfire flooding. In addition, 10 critical facilities and 593 buildings are directly within debris flow risk zones.

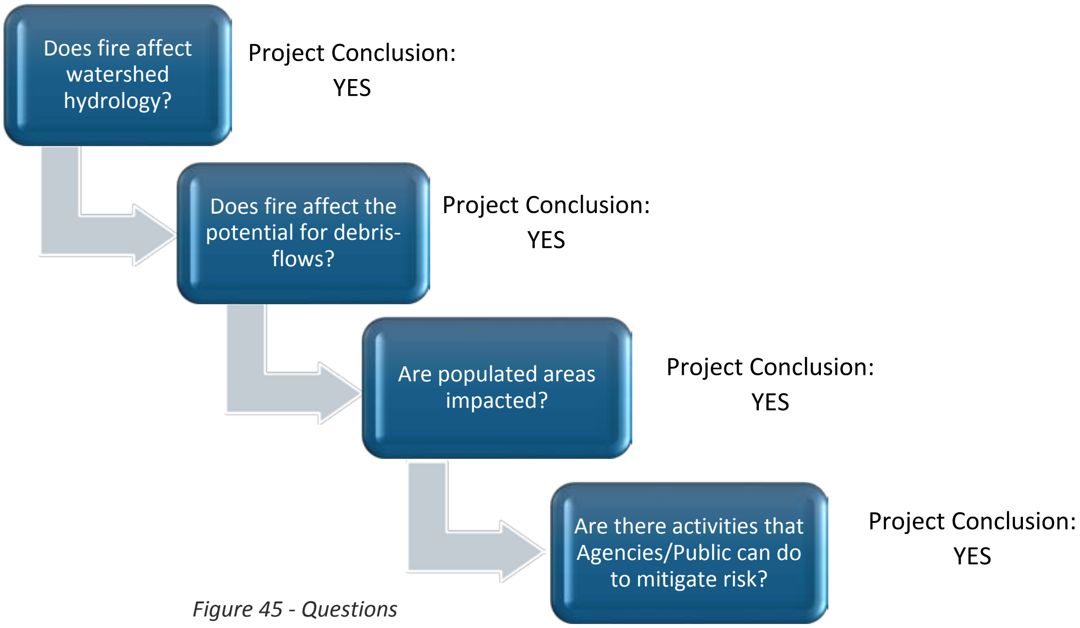
Does fire affect watershed hydrology?
Project Conclusion: YES
Does fire affect the potential for debris-flows?
Project Conclusion: YES
Are populated areas impacted?
Project Conclusion: YES
Are there activities that Agencies/Public can do to mitigate risk?
Project Conclusion: YES

Figure 45 - Questions

To better understand the specific impacts to local communities, two pilot areas were selected for a detailed pre- and post- wildfire flood and debris flow analysis. These detailed studies sought to determine an answer to the questions in Figure 45 and understand the severity and implications of those answers. In all cases the answer is **YES**.

Post-fire debris flows are likely in both pilot study areas if a wildfire with enough high to moderate burn severity on upper slopes of watersheds occurs. In addition, debris flows erode and scour channels as they travel downslope, releasing sediment for additional transport by hyperconcentrated flows and sediment-laden flood flows. While debris flows may not travel far enough to directly impact houses, infrastructure or other critical facilities, they will indirectly impact these areas of concern by eroding and transporting released sediments via hyperconcentrated sediment and flood flows.

In the Williams study area, debris flows entering and impacting City Dam reservoir is a major concern. Post-fire sediments could significantly decrease the capacity of the reservoir and compromise water quality. Downstream areas will see a significant increase in flooding and sedimentation. The number of structures and critical facilities impacted by flood depths greater than 1 foot in the 100-year event could increase by 350% in the event of a fire.

Within the Fort Valley study area, the major concern is hyperconcentrated sediment and flood flows entering developed areas, similar to the post-Schultz-Fire flooding. Channels on the fans at the base of the San Francisco Peaks could erode and evolve with each storm, resulting in unexpected flood pathways and newly eroded channels. Sediment from newly eroded channels could impact developed areas via hyperconcentrated sediment and flood flows, or perhaps by minor debris flows if temporary debris dams form and breach in the upstream channels. Downstream areas will see a significant increase in flooding and sedimentation. The number of structures impacted by flood depths greater than 1 foot in the 100-year event can increase by 255% in the event of a fire.

In both areas, post-fire flood hazards differ significantly from no-fire flood hazards, and include large amounts of land currently not mapped as floodprone.

Coconino County has the opportunity to partner with other stakeholders to affect change within the watersheds and reduce risk to the public and existing infrastructure. Potential stakeholders may include:

- **City of Williams –** A significant portion of the City is at risk.
- **City of Flagstaff –** Future studies may indicate similar impacts to portion of Flagstaff.
- **United States Department of Agriculture (USDA) – Coconino and Kaibab National Forests –** Wildfire poses a significant risk to the health and management of the existing forest.
- **Arizona Department of Emergency and Military Affairs (DEMA)/ Federal Emergency Management Agency (FEMA)** - Possible Pre-Disaster Mitigation (PDM) Grant funding that can help with pre-fire mitigation implementation.
- **Arizona Department of Environmental Quality (ADEQ) – Water Infrastructure Finance Authority of Arizona (WIFA) -** Possible partnering opportunity to maintain the water quality of the Williams Water System.
- **Arizona Department of Transportation (ADOT)** – Several ADOT facilities have the potential to be impacted in the event of a post-wildfire flood.
- **Energy Transfer (Owns Transwestern Pipeline**) – A portion of the pipeline may be impacted by post-wildfire flooding and debris flows.

Other potential partners include public and private utilities (gas, water, electric, cable, phone, etc.), the Federal Highways Administration, FEMA, and the BNSF Railroad.

In Northern Arizona, trends of increasing wildfire size and severity have placed many people and the infrastructure that serves them at risk from wildfires and the aftermaths of fires. Forest treatments to restore forest health are critical to the reduction of fire risks and the potential for post-wildifre flooding and debris flows. Forest treatments which are planned as a part of the Bill Williams Mountain Restoration Project can reduce the potential for a severe wildfire fire if they are implemented before a fire happens. In the Fort Valley area, however, modeling suggests that treatment efforts will reduce risks only if treatments can occur on the whole mountain, including within the wilderness area. Debris flows are generated on the steep upper slopes of burned basins which, in this study area is within the wilderness area. This will require coordination with environmental organizations, Congress and USFS.

Coconino County has been proactive in understanding the general risks within the County and the specific risks within the pilot watersheds. Wildfires will continue to be a risk to other areas within the County and the extent of that risk should be identified in subsequent studies.

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